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Station-Based Lift for Intercity Buses

Design Criteria

Prepared for the
Transportation Development Centre

DELCAN ENGINEERS PLANNERS ARCHITECTS

in association with

TES Limited

Rutenberg Design Inc.

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STATION-BASED LIFT FOR INTERCITY BUSES DESIGN CRITERIA

DECEMBER 1987

DELCAN

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Un sommaire en français de ce document est inclus avant la table des matières.

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17 Abstract

The initial work plan for this study was concerned with the evaluation of a specific device, the Kingston Transfer Chair, a boom-mounted seat intended to assist the mobility impaired in boarding/deboarding intercity buses. An in-service demonstration was originally planned, but the results of a preliminary evaluation showed that the device failed to satisfy basic safety, structural and functional requirements. Consequently, the work plan was revised to focus on the development of generally applicable evaluation and design criteria for station-based lifts. A thorough review of the constraints limiting the deployment of a station-based lift including terminal as well as operational and ergonomic considerations. The resulting design criteria fall into seven major categories, namely: (i) exterior appearance; (ii) device/coach interface; (iii) passenger safety and comfort; (iv) functional adequacy; (v) accessibility; (vi) technical requirements; and (vii) control system. A weighting scheme for the design criteria and a sample evaluation and scoring sheet are also presented.

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17 Résumé

L'objectif premier de cette étude a été l'évaluation en service d'un dispositif particulier, le siège de transfert Kingston, conçu dans le but d'aider les voyageurs ayant une incapacité motrice à monter à bord des autocars et à en descendre, au moyen d'un siège coulissant le long d'une flèche. Les résultats de l'évaluation ayant montré que le siège n'a pas satisfait aux exigences structurelles, ergonomiques et de sécurité définies, on en a profité pour adopter un nouvel énoncé des travaux dont l'objet serait d'élaborer des critères généraux de conception et d'évaluation propres aux dispositifs de transfert non embarqués. Après un examen approfondi des difficultés rencontrées lors des essais, l'étude propose des critères en vue de définir les conditions menant à la satisfaction des exigences d'ergonomie, d'exploitation et de performances. Ces critères ressortissent à sept grands domaines: i) aspect extérieur; ii) interface dispositif-autocar; iii) confort et sécurité du voyageur; iv) fonctionnalité; v) facilité d'accès; vi) caractéristiques techniques; vii) commandes. Enfin, l'étude propose une méthode de pondération des critères de conception à laquelle est joint un spécimen de feuille d'évaluation pondérée.

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SUMMARY

Transport Canada, in support of its objective to facilitate barrier-free transportation for all individuals, has focussed considerable effort on fostering the development of devices which overcome barriers inherent in the transportation system. One such barrier - stairs in intercity buses - can create serious difficulties for many elderly and disabled passengers.

The initial work plan associated with this study focussed on the evaluation of the Kingston Transfer Chair as a device intended to assist the mobility impaired in boarding/deboarding intercity buses. The evaluation of this device was originally structured around three phases: a pre-demonstration phase in which the transfer chair device was evaluated with respect to basic functional ergonomic and structural criteria; an in-service demonstration of the device in five bus terminals; and a review of the results of the first two phases, resulting in proposed modifications and/or improvements to the device and an estimate of its market potential.

The Kingston Transfer Chair was designed as a relatively simple device which, once positioned in the doorway of the bus, would be able to transport a disabled person seated in the chair up into the bus through the conventional doorway opening. The chair is raised by means of an electrically driven feedscrew.

However, the results of the first phase indicated the Kingston Transfer Chair, as delivered in late 1985, failed to provide the basic safety, structural and functional requirements for the device to be placed in service. Consequently, the second and third phases of the initial work plan were revised to provide a work program which concentrated on the development of generally applicable evaluation and design criteria for station-based lifts.

An important step in formulating the design criteria was a detailed review of the problems encountered during the mechanical and ergonomic testing of the Kingston Transfer Chair. The transfer chair, as tested, employed an electrically driven feedscrew to raise and lower the chair. The feedscrew rotates at high speed, is completely exposed and is centered below the seating position of the user. The close proximity of the open feedscrew to the user creates an undesirable situation whereby the user's clothing or unprotected lower limbs could become entangled in the mechanism. This is of particular concern as many of the potential users have limited use and/or control over their lower limbs. It is important that any proposed device protect against this potential hazard.

Another major concern, aside from the safety issues, was the inaccessibility of the device to potential users with varying degrees of mobility restrictions. It became obvious during the ergonomic evaluation that a great number of basic requirements of the user and the operator were not adequately considered in the design of the Kingston Transfer Chair. Some of the findings which relate to the user include the following:

- The chair is relatively inaccessible as barriers exist on all sides (control panel to the left, canes and footrest in the front and the location of the bus door prohibiting access from the right). These obstructions restrict the conventional means of transferring persons between chairs.

- The canes are the only visible means of support, however, as physical force is applied, these canes may rotate.

- The seat height is approximately 57 cm from the ground, approximately 7.5-10 cm higher than the standard wheelchair. This means that significant additional effort is required to transfer a user from a wheelchair. Also, when approached from a standing position (i.e. elderly users) the seat requires a step to aid the user; the footrest is the only visible means of obtaining this height advantage, but it has not been designed to support the weight of the user.

Knowledge of the influencing factors associated with a station-based lift early in the design process ensures that the final design incorporates the necessary elements to minimize the impact of the constraints imposed by those factors. These factors were identified as part of the revised work program and are based on the extensive experience gained through the mechanical and ergonomic testing of the Kingston Transfer Chair. In addition, technical investigations were undertaken to gain an appreciation of operational environments. The influencing factors relate to the following main groups, namely:

- **Terminal/site constraints** - Information with respect to the environment in which a potential station-based lift will operate is fundamental to the overall reliability and ultimately the success of the device. To gain a thorough understanding of the device's operating environment, a number of field trips were made to bus terminals in the Quebec City-Windsor corridor.

- Some of the specific conclusions and recommendations obtained as part of this activity include the requirement for designated pre-boarding areas and the desirability of having the device designed for operation by a single person. Other technical data gathered relate to physical constraints such as door widths and platform characteristics.

- **Coach constraints** - A number of vehicle constraints were identified, and specific bus modifications examined to assess their feasibility and impact. The primary finding of this investigation was that the development of a station-based lift is severely restricted by the space available in the bus entrance/stairwell area. Consequently, minor bus modifications have been suggested, including a removable safety bar/vanity panel, increased door angle opening and removable armrests. These proposed

modifications would improve the operating environment in which the transfer device would function. However, it is also understood that all potential bus modifications would have to be considered in conjunction with the specific needs or requirements of a proposed lift and be developed for adequate safety, function and cost effectiveness as an integral component of the overall design.

- **Operator constraints** - Currently, intercity coach lines are providing assistance to individual travellers (particularly the disabled population) on an ad hoc basis, which typically involves the manual lifting of the passenger from the platform into the bus; consequently, the development of a device to aid disabled persons boarding intercity buses must reduce the current exposure to physical injury to both the person providing assistance and the person being assisted. In addition, it is felt that staffing requirements associated with the use of any device developed should be restricted to a single person to ensure efficient and effective application.

- **User constraints** - Candidate users of a station-based lift were identified on the basis of several factors, including: the passenger's ability to negotiate stairs through the front door of the bus, the passenger's ability to negotiate the bus aisle, the space requirements of the passenger and the person(s) providing assistance in transferring the passenger to/from a seat, and the storage space requirements for the passenger's mobility aids. Potential users of the device include elderly and disabled passengers who are capable of remaining seated (unrestrained in a standard bus seat) for the duration of the trip and travelling with only compact, lightweight mobility aids (including folding wheelchairs). Although this definition does not encompass the entire mobility disadvantaged population, it does represent a sufficiently large component of this population to warrant serious consideration.

The recommended design criteria have been formulated based on a thorough review of the constraints affecting the design and operation of a station-based lift. The criteria consider operational, ergonomic and performance factors, which focus on seven major design elements, namely:

(i) exterior appearance;
(ii) device/coach interface;
(iii) passenger safety and confort;
(iv) functional adequacy;
(v) accessibility;
(vi) technical requirements; and
(vii) control system.

Some of the design criteria involve quantifiable factors such as relative cost, performance, efficiency, reliability and compatibility with existing systems. Others are of a more subjective nature and address safety, quality, comfort,

simplicity and adaptability concerns. The design criteria provide a basis for choosing the preferred solution among alternatives and provide guidelines for optimizing various alternatives. In addition, a weighting scheme has been developed to ensure a structured and consistent application of the evaluation procedures.

While the Kingston Transfer Chair concept is a valid one, considerable effort would be required to redesign the transfer chair (as tested) so that it could be introduced to the public in a demonstration project. Conclusions and recommendations developed as part of the revised work program include:

- Target user groups include all persons capable of remaining seated (unrestrained in a standard coach seat) and travelling with compact, lightweight mobility aids.

- The current 24-hour advance notification will remain a requirement, and passenger preboarding will, in all likelihood, be required to allow for the appropriate arrangements to be made to transfer the passenger.

- The device should be designed for operation by a single person, with a minimum level of physical effort required to assist the passenger.

- Vehicle constraints dictate the need for a small number of minor bus modifications to improve the operating environment of the device. These modifications should, however, be considered in conjunction with the specific requirements of a station-based lift.

- A structured approach to the design and development of a station-based lift is required. Such an approach would include the conceptual design including full scale mock-ups and evaluation, functional design, prototype development, in-service demonstration and production model development.

SOMMAIRE

À titre de contribution au programme qui vise à réduire les barrières gênant la pleine accessibilité des transports, Transports Canada a consenti un effort considérable à l'étude et à la réalisation de dispositifs permettant d'abattre cet obstacle omniprésent qu'est l'escalier, plus particulièrement l'emmarchement des autocars, obstacle que personnes âgées et handicapés trouvent souvent infranchissable.

La première réalisation dans le cadre de ce programme a été le siège de transfert Kingston, dont l'évaluation devait, à l'origine, se faire en trois étapes: démonstration préliminaire par rapport aux exigences fonctionnelles, ergonomiques et structurelles de base définies; démonstration en service dans cinq terminus d'autocars; et examen des résultats des deux premières étapes débouchant sur des suggestions en ce qui concerne les perfectionnements ou les modifications à apporter et sur une estimation du potential commercial.

De conception simple, le siège de transfert Kingston, une fois son extrémité supérieure fixée à la porte de l'autocar, devait permettre de transférer un voyageur ayant pris place dans le siège depuis le quai jusqu'à l'intérieur de l'autocar et vice versa. Ce siège de transfert est mû par une vis sans fin entraînée électriquement.

Toutefois, les résultats de la première étape ont montré que le siège, dans sa version livrée vers la fin de 1985, ne satisfaisait pas aux exigences et qu'il ne pouvait donc pas être mis en service; on en a alors profité pour remplacer les deux étapes suivantes par un nouveau programme dont l'objectif a été d'élaborer des critères généraux de conception et d'évaluation propres aux dispositifs de transfert non embarqués.

Pour la formulation des critères de conception, une des étapes importantes a été l'étude approfondie des difficultés rencontrées lors des essais mécaniques et ergonomiques du siège de transfert Kingston, qui, comme on l'a dit, comporte une vis sans fin électrique. Or cette vis, qui tourne très rapidement, est sans portection aucune et, de plus, se trouve au-dessous et très proche du siège dans lequel le voyageur est assis. Cela représente une situation très dangereuse, les vêtements du voyageur, voire un de ses membres inférieurs, pouvant être pris dans l'engrenage; d'autant plus que les usagers se rencontrent parmi des gens qui, en raison de leur état particulier, maîtrisent peu ou pas leurs membres inférieurs. Il faut donc absolument se prémunir contre un tel risque.

L'autre grande faiblesse de ce dispositif, outre son insécurité, est la difficulté d'y prendre place pour quiconque souffre d'une incapacité motrice à un degré quelconque. En effet, les essais ergonomiques du dispositif ont montré que, dans sa conception actuelle, certains facteurs importants, tant pour les voyageurs que pour l'exploitant, n'ont pas été suffisamment prise en compte. Voici quelques-unes des constatations concernant les usagers:

- Le siège est entouré de toutes sortes d'objets formant obstacle: à gauche du voyageur, le pupitre de commande; devant, les têtes de canne et l'appui-pieds; à droite, la porte de l'autocar. Tous, de surcroît, peuvent gêner le transfert du voyageur d'un siège à l'autre.

- Les têtes de canne sont supposées servir d'appui, mais dès qu'on s'en sert, elles ont tendance à pivoter.

- Le siège se trouve à environ 57 cm du sol, soit de 7,5 à 10 cm plus haut que le fauteuil roulant standard, ce qui rend beaucoup plus laborieux le transfert entre les deux sièges. De même, dans le cas d'une personne ambulatoire (une personne âgée, par exemple), un marchepied serait nécessaire; certes, il y a l'appui-pieds, mais il n'est pas assez solide pour supporter tout le poids d'une personne.

Si tous les paramètres pouvant avoir une influence déterminante sont dégagés tôt dans la conception d'un dispositif non embarqué et sont dûment pris en compte, on parvient à réduire les contraintes correspondantes. Les essais ergonomiques et mécaniques poussés qui ont été faits sur le siège de transfert Kingston ont permis de reconnaître les facteurs ayant eu le plus d'influence ainsi que les contraintes propres au milieu dans lequel un dispositif de transfert doit fonctionner. Les paramètres et les contraintes, ainsi identifiés, ressortissent aux quatre grands groupes suivants:

- **L'endroit** - La fiabilité et le bon fonctionnement du dispositif dépendent avant tout d'une connaissance approfondie du milieu où il est mis en service. Un certain nombre de terminus d'autocars dans le corridor Québec-Windsor ont été examinés sous cet angle.

  Quelques-unes des conclusions tirées et des recommandations formulées à cet égard ont trait à la nécessité de délimiter une zone d'embarquement assisté, réservée aux voyageurs ayant une incapacité et de concevoir un dispositif pouvant être actionné par un seul opérateur. Les autres données techniques mesurées ont été la largeur des portes et les caractéristiques d'aménagement des quais.

- **L'autocar** - À partir des contraintes liées au véhicule, des modifications ont été envisagées et soumises à l'examen en regard de la faisabilité et de l'impact. Étant donné que la contrainte la plus astreignante relevée est l'exiguité de l'escalier et de son puits, les modifications proposées portent sur l'ensemble panneau d'escalier - main courante qui devrait être du type démontable, l'élargissement de l'espace d'accès par un angle d'ouverture plus large de la porte et le remplacement des appui-bras le long du couloir par d'autres amovibles. Ces modifications devraient rendre le dispositif plus performant; il convient cependant de faire remarquer qu'elles doivent être adaptées au type de dispositif utilisé et déboucher sur une sécurité et des performances techniques et économiques accrues, résultant d'une intégration conceptuelle réussie.

- **L'exploitant** - À l'heure actuelle, les entreprises de transport par autocar n'ont aucune procédure prédéfinie quant à l'assistance à un voyageur incapable de monter à bord par ses propres moyens. La plupart du temps, ces gens sont transportés à bord par la force des bras. Donc, l'objectif primordial en ce qui concerne l'exploitant est d'avoir un dispositif d'embarquement qui permette d'éliminer les risques de blessure tant pour la personne qui aide que pour celle qui est aidée. Un autre facteur important à considérer est la nécessité d'étudier un dispositif pouvant être actionné par un seul préposé, dans un but d'efficacité et d'économie.

- **Le voyageur** - Les usagers potentiels du dispositif ont été déterminés d'après un certain nombre de facteurs, dont les suivants: incapacité d'emprunter l'escalier de la porte avant sans assistance; capacité de se déplacer dans le couloir central; espace nécessaire pour effectuer le transfert d'un siège à l'autre; espace nécessaire pour ranger l'appareil d'aide à la motricité.

  Le dispositif non embarqué est prévu pour les personnes âgées ou souffrant d'incapacité qui sont capables de faire tout le trajet dans un siège ordinaire de l'autocar sans devoir être immobilisées et qui n'ont besoin que d'une aide à la motricité légère et peu encombrante pour se déplacer, y compris un fauteuil roulant pliant. Malgré les restrictions qu'elle implique, cette définition de l'utilisateur reste suffisamment large pour englober une forte proportion des voyageurs à mobilité réduite, au point de mériter d'être sérieusement prise en considération.

Les critères de conception proposés sont fondés sur un examen approfondi des caractéristiques que doit posséder un dispositif de transfert non embarqué et des contraintes qui régissent son utilisation. Ces critères sont de trois ordres - opérationnels, ergonomiques et de performances - et ressortissent aux sept grands domaines suivants:

i) aspect extérieur;
ii) interface dispositif-autocar;
iii) confort et sécurité du voyageur;
iv) fonctionalité;
v) facilité d'accès;
vi) caractéristiques techniques;
vii) commandes.

Certains concernent des facteurs objectifs comme le coût relatif, les performances, l'efficacité, la fiabilité et la compatibilité avec d'autres dispositifs. D'autres font appel à des facteurs plus subjectifs comme la sécurité, la qualité de service, le confort et la facilité de fonctionnement et d'adaptation. Tous, cependant, veulent guider l'exploitant dans le choix de l'option à privilégier et dans le relèvement de certaines performances. En outre, une méthode est proposée permettant de faire la pondération des critères afin d'arriver à une évaluation structurée et cohérente du dispositif considéré.

Bien que très valable dans sa conception, le siège de transfert Kingston nécessitera quant même une réétude générale avant de pouvoir être mis en service expérimental. Voici les principales recommandations formulées:

- Le dispositif doit pouvoir être utilisé par des personnes qui sont capables de faire tout le trajet dans un siège ordinaire de l'autocar sans devoir être immobilisées et qui n'ont besoin que d'une aide à la motricité légère et peu encombrante.

- Le préavis de 24 heures continuera d'être exigé, et probablement aussi l'embarquement préalable, afin de permettre la préparation et le déroulement sans encombre de l'opération d'embarquement et de transfert.

- Le dispositif doit pouvoir être actionné par un seul opérateur auquel il ne sera pas demandé de gros efforts pour aider le voyageur à mobilité réduite.

- Les contraintes relatives à l'autocar montrent qu'un petit nombre de modifications mineures seraient nécessaires, mais elles devraient être spécifiques au type de dispositif considéré.

- La mise au point du dispositif doit être l'aboutissement d'un processus bien structuré devant comprendre les étapes suivants: étude conceptuelle; réalisation et évaluation de maquettes en vraie grandeur; étude fonctionnelle; mise au point du prototype; mise en service expérimental; mise au point du modèle de série.

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1.0 BACKGROUND

A recent world-wide estimate of disabled people with mental, physical or sensory impairment is more than 500 million[1]. In Canada, while the numbers are smaller, the scope of the problem is of major importance. A recent survey undertaken by Statistics Canada[2] indicates 2,448,000 Canadian adults (almost 13 percent of the adult population) and 302 000 children up to age 15 may be considered disabled in this country. Of these, two thirds have mobility problems and many use special transportation aids to assist them in everyday life.

The survey further classified the types of disability into mobility (walking and moving about); agility (restriction in body movements), eyesight, hearing and speaking. For those 65 and over, again mobility difficulties were the most prevalent, numbering over 650 000 - a significant portion of the Canadian population. This trend can be expected to become more pronounced as Canadians, increasingly, live longer and the elderly as a proportion of the whole population continue to grow.

Consequently, Transport Canada as part of its objective to facilitate barrier-free transportation to all individuals, has focused considerable effort to develop devices which overcome barriers inherent in the transportation system. One such barrier - stairs leading onto intercity buses can create mobility difficulties for many segments of the elderly and disabled population. A large portion (40-50 percent) of the respondents in the Statistics Canada Survey, commenting on various difficulties encountered in long distance transportation, indicated the major problem is related to boarding and seating. Therefore the development of a station based lift to transport passengers from outside the bus to the coach aisle would overcome many of the problems associated with the intercity coach stairwell. The station based lift was originally developed based on the need for a relatively simple device capable of transferring passengers into or out of intercity buses without necessitating significant modifications to the current intercity bus fleet.

The primary objectives of the device based on discussions with Transport Canada and intercity coach operators have been formulated as follows:

- to facilitate the transfer of persons who have difficulty or who cannot climb stairs into or out of intercity buses; and
- to reduce the risks taken by bus terminal employees by eliminating the need to carry non-ambulatory passengers into/out of buses.

Source (1) Mobility CUTA Newsletter, Volume 1, Number 2, June 1987.
(2) Report of the Canadian Health and Disability Survey, 1983-1984, Statistics Canada, Health Division, July 1986.

2.0 INTRODUCTION

The study was undertaken in two primary phases. Phase 1 focused on the evaluation of the "Kingston Transfer Chair", a station based lift. The Kingston Transfer Chair was a prototype intended to assist the mobility impaired in boarding/deboarding intercity buses. The evaluation of this device originally consisted of three major tasks: a pre-demonstration period in which the transfer chair device was to be evaluated with respect to basic functional, ergonomic and structural criteria, an in-service demonstration of the device in five bus terminals, and finally, a eview of the results of the first two tasks, where potential modifications and/or improvements to the device were to be identified and its market potential estimated.

The results of the first major task however indicated the "Kingston Transfer Chair" device as delivered in late 1985 failed to provide the basic safety, structural and functional requirements necessary to enable the device to be placed in service. These findings were based on a detailed ergonomic evaluation and mechanical test program and are documented in Appendices C, D and E of this report. Consequently, the second and third major tasks of the initial work plan were revised resulting in a modified work program (Phase 2) which forms the basis of this report.

The failure of the "Kingston Transfer Chair" to meet basic safety, structural and functional requirements for a station based lift device required a reassessment of the overall objective and/or problem statement associated with the development of such a device. While the objectives of the device remain unchanged, significant information was required to clearly identify the constraints which a device must satisfy. This information is also required to accurately define the exact nature of the problem to ensure the successful introduction of a station based lift device. Consequently, the criteria developed can be used either in the design process or in the evaluation of a station based lift device for intercity buses.

Based on the foregoing, the primary objective of this phase of the study is to develop and formulate design criteria as well as to identify influencing factors associated with the development of a station-based lift device for intercity bus transportation. These objectives are to be achieved within the scope of the revised work program which focuses on the identification of specific problem areas which were identified during the ergonomic and mechanical testing of the "Kingston Transfer Chair"; the identification of the influencing factors (the environment within which the device operates) and the formulation of design criteria.

3.0 PROBLEM AREAS - TRANSFER CHAIR CASE STUDY

The "Kingston Transfer Chair" is a device which was developed to enhance intercity travel for passengers with mobility restrictions by providing a means to move passengers up or down the stairwell of intercity buses. The Transfer Chair is a relatively simple device which is positioned into the doorway of the bus such that the upper end of the boom is near the bus driver's seat (see Figure 1 and Photograph 1). A disabled person may then be positioned into the chair and raised by means of an electrically driven feedscrew into the bus through the conventional doorway opening.

An important component of this study was to test and evaluate the suitability of the Kingston Transfer Chair system as a boarding/deboarding device for the elderly and disabled with respect to intercity transportation. Detailed results of the ergonomic evaluation, the mechanical test findings and their implications are contained in Appendices C, D and E.

To summarize, the mechanical and ergonomic testing of the Kingston Transfer Chair clearly illustrated that while the concept of a transfer device appears valid, the transfer chair as delivered failed to perform sufficiently well to be introduced to the disabled community. Serious safety concerns as well as functional and structural aspects had to be addressed prior to its introduction via a demonstration project.

It should be noted, however, that these test findings are based on the Transfer Chairs which were delivered in late 1985 and it is understood that subsequent enhancements have resulted in the mitigation of several of the problems identified.

The ergonomic and mechanical testing of the "Kingston Transfer Chair" provided an appreciation of the complexity of the problem of boarding/deboarding passengers with limited mobility onto intercity buses. The intent therefore is not to rate or judge the performance of this particular device but rather, to highlight the fundamental problems and/or deficiencies which were identified during the test program in order that these may be clearly documented and consequently avoided in the future.

The sections which follow present an overview of the test findings with material grouped into three major categories, namely safety, structural integrity and functional adequacy.

PHOTOGRAPH 1

Prototype Transfer Chair

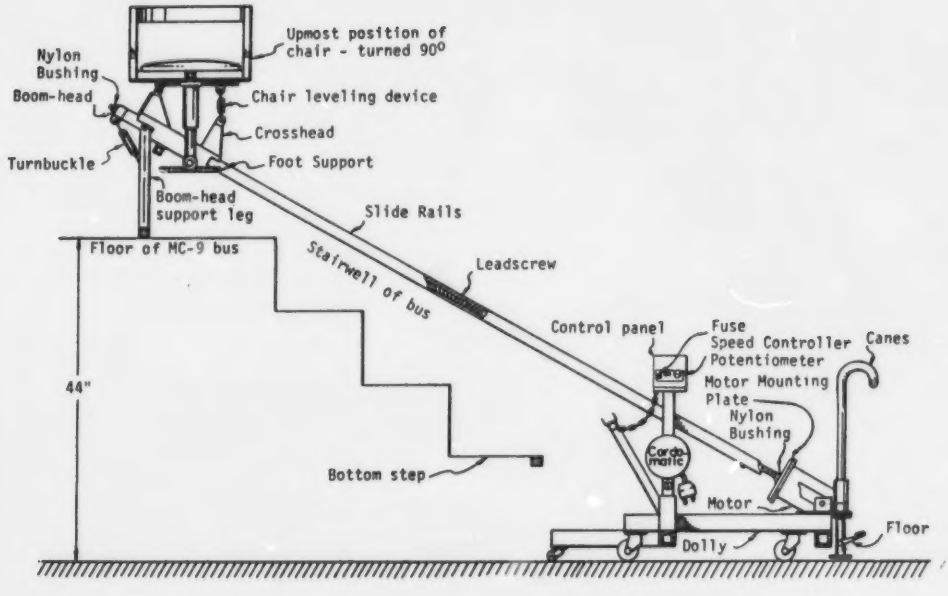

FIGURE 1

3.1 Safety

A transfer device should provide an adequate level of safety for the passenger and be perceived by the passenger as being a safe and attractive device with which to be associated.

The first requirement is a critically important element for any publicly used system. Although there are no current standards for a transfer chair device, there are several regulations, standards and guidelines developed for other modes of transportation which contain sections which may be equally applicable to the transfer chair systems. These include the Canadian Standards Association (CSA) CAN3-D409-M84 and the U.S. Department of Transportation UMTA-CA-06-0101-79-1. These standards make provisions for such factors as:

- load capacity
- rate of ascent/descent and "free fall"
- maximum acceleration levels
- control systems
- ramp requirements - size/slope/surface, etc.
- recommended safety factors for mechanical components
- general size/space requirements.

The second requirement, the perception of safety, may be considered very subjective, but nevertheless requires considerable attention since passengers may refuse to use a device if it is perceived to be unsafe. Since the ultimate measure of success for any device is based on its acceptance by potential users then the perceived safety of the device becomes an essential element and consequently must be given due consideration.

The safety related problem areas identified relate primarily to the passenger seat, the drive mechanism and the control system.

To board/deboard handicapped passengers onto an intercity bus requires safely transporting them up the stairwell entrance area of the bus. It has been assumed that the passenger would be seated during this process. Due to the limitations of the handicapped traveller, the chair must meet specific requirements to appropriately accommodate them.

In accordance with the Canadian Standards Association (CSA) Standard CAN3-D409-M84, a seat for a handicapped person must have a minimum width of 38 cm and a depth of 38-43 cm. Although not required in terms of a restraint system, a lap belt would be a necessary safety precaution since some handicapped travellers have limited or restricted upper body control. The belt should be perceived as a safety/comfort belt and be designed to ensure the seated passenger remains properly positioned within the chair.

Access to the transfer chair, and the height of the seat are two very important elements in the design of a station based lift device. It is essential that the device be responsive to the needs of the group of persons to which the device is intended to serve. For example, differences in seat elevation between the Transfer Chair and a standard wheelchair result in the device offering insignificant advantages over current manual lifting procedures due to the level of effort required to transfer a person from a standard wheelchair to the transfer device.

Serious safety hazards may develop when passengers perceive components as being capable of supporting aids when, in fact, they have not been adequately designed to withstand the load which is to be applied. For the safety of the passenger, supports must remain immobile when in use, while remaining flexible enough to be removed on occasion so as not to block access to the device. In addition, should footrests be used, they should be designed similarly to those equipped on a standard wheelchair to withstand the weight of a 95th percentile male.

While it is understood that several drive systems may be appropriate for a transfer chair, such as an electric motor and ballscrew thread, hydraulic/pneumatic motors and chain or cable drive mechanisms, it is important that adequate safety precautions are included in the system selected.

For example, the weight of a passenger must not allow the device to continue moving once power to the drive mechanism has been switched off.

A problem often encountered with high speed rotating parts is the lack of adequate shielding to protect the passenger from accidental entanglement. The risk of the passenger or loose clothing making contact with these parts is completely unnecessary and unacceptable. Design techniques must be applied to ensure no exposure exists between passengers and/or loose clothing with any moving parts.

In general, hydraulic systems have the advantage of good control, automatic braking and limited parts motion; however, they are typically quite expensive to purchase, install and control. Pneumatics have similar advantages but may not be well suited given the pressure and supply volume required to meet the necessary power levels. The range of motion needed in a station based lift device is also not highly conducive to hydraulic/pneumatic cylinders. While staged cylinders or linear actuators with motion increasing ratios are available, their cost may be considered prohibitive for this type of device.

Since exposed rotating parts are unacceptable, alternatives include transferring the rotating motion of a motor to linear motion through a simple gearbox combined with a chain, cable or similar linear mechanism. The most simple and inexpensive form of such a device is a winch. Winches provide very high loading capacities, operate at a reasonable speed, require moderate power supply and usually incorporate automatic braking.

The remaining safety concerns relate to the overall control system. A fundamental safety feature associated with the control system should be that under no condition would there exist a potential for unattended operation of the device. In addition, the control mechanism should have an automatic reset switch in the event of a power interruption which would return all switches to the "off" position. Also, separate switches for upward/downward control which respond only to continuous pressure would be an appropriate means for control. Care should be exercised to ensure information which is to be conveyed on the control panel be absolutely clear. For example, "up/down" or "ascend/descend" descriptors should be used as opposed to "forward/reverse" and their location on the panel should also support their function. These instructions should be provided in both official languages and maximize use of symbols and/or colours to clarify and highlight the various functions. Sections from CSA Standard CAN3-D409-M84 which are relevant to a station based lift device control device are provided in Appendix A.

3.2 Structural Integrity

It is expected that the station based lift device will be used on a highly variable basis depending on the importance of the bus terminal and the population base it serves. Reliability therefore becomes an important factor since the device must perform adequately both structurally and operationally each and every time the device is used, even though it may remain unused for long periods of time at some locations.

A device which remains inactive during longer periods of time than it is actually operating is more susceptible to inadequate care and attention. It is very difficult through the normal course of occasional use to deal with minor variations and/or deterioration in performance levels and operating characteristics and/or deflections which occur over the life of the device. Therefore, without adding the burden of frequent thorough inspections, it becomes vitally important to design the device for long periods of inactivity while maintaining maximum safety and functional performance.

The device, while in operation, is subjected to cyclic usage and, consequently, will be prone to fatigue failure after some time in service. Therefore, the evaluation of any device should include cyclic testing representative of an extended service period to determine when failure may occur given general operating conditions. From previous tests performed on the "Kingston Transfer Chair", typical cyclic or fatigue problems were readily apparent early in the test program including crack propagation and/or fracture of welded assemblies (usually from areas of high stress concentration), as well as excessive component wear and deformation/deflection.

These types of visual deterioration contribute to a decreased level of perceived safety to the passenger as well as create significant safety concerns. Generally, problems of this nature are the result of inadequate strength of the structural members, inappropriate application of safety factors (which should be in the order of 5), failure to follow appropriate design practices which avoid stress concentrations, failure to consider cyclic loading and improperly selection of components and materials, particularly those subjected to wear and dynamic impact.

In areas designed to be subjected to wear, improper selection of mating materials may cause accelerated wear or create a greasy, dirty film which could easily be transferred to a passenger's clothing. The latter situation will occur for example when aluminum is in contact with nylon pads. When aluminum is rubbed, a thin protective layer of oxide is removed and the aluminum oxidizes again, very quickly, resulting in a buildup of oxide. Strips of ultra high molecular weight polyethelene (UMHW), which is the toughest commercially available friction material, fixed to adjacent wearing members would produce a clean, non-wearing friction surface that would not require lubrication.

3.3 Functional Adequacy

As identified previously, one of the safest ways to transfer passengers into/out of an intercity bus is for the passenger to be in a seated position. The chair or seat, due to the limited space available within the coach stairwell and the variation in floor heights, is required to perform specific functions. The seat of the device should be capable of swivelling to facilitate transferring passengers to the device from a wheelchair and from the device to the coach seat facing either forwards or rearwards. Also, assuming the seat will be capable of swivelling, it is important to incorporate a locking mechanism to keep the seat from swivelling while travelling up and down the stairwell to minimize contact between the bus and the passenger or the transfer chair. Appropriate hardware for this type of swivel action could be a hardened pivot shaft and thrust washer/bearing(s) specifically designed for this purpose. To retain a fairly simple and cost effective design, this function would likely be best suited for an oil impregnated bronze bushing incorporating a thrust collar. The purchase and installation costs would be low and no lubrication/maintenance would be necessary. The rotational locking mechanism could be one of many suitable designs including fully automatic or manual operation.

In addition, based on review of the "Kingston Transfer Chair", it was observed that the base of the chair undergoes significant angular changes during operation. Consequently, a mechanism to adjust the seat angle to ensure it remains level is a requirement. The hardware chosen should ensure that the adjustment mechanism is not loose fitting which would cause rattling and the

perception of inadequate safety. Typically, the design should utilize a single adjustment knob, large and easily accessed, with a spring loaded locking adjustment mechanism to provide safe, rattle-free operation and a secure feeling to the passenger.

The device should be operated via a remote control panel preferably by a single operator who should be prepared to assist the passenger when transferring to or from the device. It is therefore important to have unobstructed access to the chair thereby ensuring a high level of mobility for the operator during operation. While a small remote control unit would assist in both these areas, this would likely increase costs significantly and properly locating a fixed control panel could ensure adequate chair access without the high cost of a remote unit. This would ensure that the operator is not impeded while assisting the passenger and that the passenger is not restricted from accessing the chair.

4.0 CANDIDATE USER GROUPS

Passengers with disabilities which limit their ability to negotiate stairs, including those in wheelchairs, are presently restricted from using one of the most efficient and economical modes of intercity transportation - the intercity bus.

In order to establish design criteria for the development of equipment which would facilitate access for the mobility disadvantaged from a station level to the bus level, it is important to focus on the target groups which may benefit from the development of such a device.

The identification of potential user groups has been based on their inability to negotiate stairs through the front door of the bus, the available storage for their aids, the ability to negotiate the aisle and the space required to properly transfer into and out of a seat.

Several groups of potential users have been identified and have been categorized, for the purposes of further analysis, into the user groups shown in Table 1.

TABLE 1

POTENTIAL USER GROUPS AND THE LEVEL OF DIFFICULTY EXPERIENCED WITH ACCESS TO INTERCITY BUSES

User Group		Level of Difficulty	
		Completely Unable to Negotiate Stairs	Great Difficulties in Negotiating Stairs
1.	Wheelchair users	X	
2.	Crutch users		X
3.	Cane users		X
4.	Walker users	X	
5.	Elderly		X
6.	Cast on lower limb		X

While this table focuses on persons with physical impairments, it is important to note that other individuals such as the visually impaired and cognitively impaired may also require assistance. However, these persons can generally negotiate the stairwells onto intercity buses.

Each of the groups identified in Table 1 is described in more detail in the following sections.

4.1 Wheelchair Users

Wheelchair users encompass a very broad range of persons with varying degrees of physical capabilities. Among wheelchair users are people who can, with or without help, transfer from their own chair to a seat or chair, others cannot transfer even with help from their own chair because of weak muscles or bone structures. Those individuals who cannot transfer from their wheelchair depend completely on the use of their wheelchair, often a customized chair, to support their daily life.

The two most prevalent types of wheelchairs are manual and converted electric wheelchairs. The manual chair is most common and can be folded and stored in the baggage hold of an intercity bus with a weight of approximately 30 to 40 kg. The second chair, the converted electric wheelchair, used by people with insufficient strength in their arms, hands and fingers to manually propel a wheelchair, is basically a standard wheelchair with the addition of batteries, motors, controls and wider tires. Some of the people restricted to these types of chairs can be transferred with substantial physical assistance; however, most cannot. These wheelchairs cannot be folded and weigh approximately 90 kg, with batteries and 65 kg without batteries. The space they require for storage is approximately 100 cm x 65 cm x 90 cm. Due to limited storage area on intercity buses and the weight of the chairs, it would be unreasonable to assume that persons capable of travelling could be accommodated with an electric wheelchair. In addition, a number of potential users of a station based lift device use an electric scooter as a mobility aid. These mobility aids are electrically powered three or four wheelers with a pivoting seat. Their weight with batteries varies between 95 and 109 kg. People using scooters can often transfer with the help of others or on their own to a seat or chair. Storage required is similar to non-foldable electric wheelchairs and passengers who rely on these devices would have to make other arrangements for the transportation of these devices in the event that it was essential that the device be available at their destination.

In general, wheelchair users, who would be capable of remaining unrestrained in a regular coach seat for the duration of the trip and could travel with a foldable manual wheelchair, would be potential candidates of a station based lift device. It is understood that some individuals would rely on the experience and physical strength of another person to perform the transfer from their wheelchair to the device and from the device to the coach seat.

4.2 Crutch Users

Persons in this category either make use of crutches as a mobility aid on a permanent basis or, in most cases, temporarily. Generally, persons in this category experience great difficulty in negotiating bus stairs.

Additional lateral space to properly make use of the crutches and a non-slip surface for stability are basic requirements for users of these aids. Lateral space requirements for users of various types of crutches is approximately 100 cm. These include the most common crutches - elbow crutches, where the body weight is supported on handles and shoulder crutches, where most of the body weight is supported under the arms. Once in the bus, the crutch users can usually move sideways through an aisle without any serious difficulties and transfer in and out of a seat especially if the seat is equipped with a removable armrest. Additional space requirements in front of the seat may be necessary if the crutch user has limited joint movement in the knee area (single full length cast).

4.3 Cane Users

Cane users may use one or two canes to enhance their mobility; however, they do encounter great difficulties using bus stairs. Typically, cane users have difficulties lifting their feet above 7 cm. Persons who use a single cane generally place it in front and to the side while in movement, however, when two canes are used, they are slightly spread laterally. The lateral utilization space is approximately 90 cm.

Generally, a cane user can, without any serious difficulty, travel down a standard bus aisle and transfer to a seat particularly when the armrest is removable. Additional support in front of the seat at waist height would be desirable to facilitate the passenger's movement in and out of the seat. It is important to be aware that some of the cane users are accustomed to having their upper body bent forward and, consequently, require a greater seat pitch. Canes can be easily stored in front of the bus coach seat.

4.4 Walker Users

Although some walker users can negotiate stairs, in most cases, they are unable to negotiate stairs, primarily due to the steep rise of assent (high shallow steps). If the step to be negotiated were much deeper and not as high as those encountered on intercity bus stairwells, some of the walker users would be capable of climbing them.

Other types of walking aids generally included in this category may be either "tripods", a frame with front casters and glides or a frame with glides only. The floor surface required to adequately accommodate the use of frame walking aids in front of the user is approximately 60 cm x 40 cm.

Walker users in most cases would be unable to negotiate the standard aisle of a bus. Consequently, provisions for a seat near the entranceway would be required. In addition, a clear distance of approximately 60 cm is required in front of the seat to perform necessary manoeuvres to transfer from a standing position to a seated position. Walking aids generally present little concern with respect to storage as they are constructed of lightweight material and can easily be stored within the baggage area of the bus.

4.5 Elderly

Elderly persons typically experience reduced stamina, balance and reaction time. Both hearing and sight may be reduced thereby making identification of edges and perception of objects, especially at night, difficult. Most elderly persons encounter significant problems when required to negotiate a step higher than 15 cm due to the problems associated with lifting their weight to that level. Hip problems, knee bending, arthritis, rheumatism, heart and breathing problems are factors which all contribute to lessening their capabilities with respect to stair climbing.

While the elderly do not require the use of specific aids, they do require supports for their hands to balance the body and a non-slip surface to stand on. They can pass through the aisle without significant difficulties but require a strong support to hold onto in front of their seat to gain access to the seat area.

4.6 Cast Users

This category focuses on those with temporary impairments restricted to lower limbs and may affect persons independent of size, age or sex. It is conceivable that persons in this category may not require any additional aids or make use of a number of aids such as canes, crutches and wheelchairs. Concerns with respect to accommodating these various aids have been identified earlier. It is important to note, however, that persons with lower limb casts often require considerable space in front of the seat to be adequately accommodated.

4.7 Potential User Groups

The development of a station based lift device should be cognizant of all of the candidate user groups discussed, namely wheelchair users, crutch users, cane users, walker users, elderly users and cast users. While individuals within each of the aforementioned categories will exhibit varying degrees of mobility, the design of a station based lift device should demonstrate sufficient flexibility to ensure that potential users from each of these groups are adequately accommodated.

The primary constraints in targeting potential user groups which fall within the scope of the station based lift device are as follows:

(i) the potential user must be capable of remaining seated (unrestrained) in a standard bus coach seat for the duration of the trip;

(ii) the potential user must be capable of travelling with compact lightweight mobility aids. A standard manual folding wheelchair would be considered a typical transportable mobility aid; however, electric wheelchairs and electric scooters (due primarily to their size and weight) would not be considered transportable.

Consequently, any passenger who meets both of the criteria identified above would be considered a potential user. Efforts are, however, required in order to provide a safe, efficient and economical device which can be used to facilitate the boarding and deboarding of potential user groups to/from intercity buses.

5.0 INFLUENCING FACTORS

Designing is an iterative process predicated on making judgments which lead to specific decisions on the basis of relevant information which is available. Therefore, the state of knowledge at any particular point in the design process is the overriding factor which shapes the final design. Consequently, information must be available early in the design process to ensure clear problem definition. For this reason the factors which influence the design of a station based lift device have been identified and are presented in this chapter.

The influencing factors which are vital elements in the development of a station based lift device intended to assist the mobility impaired in boarding and deboarding intercity coaches have been categorized into the following main groups:

- Terminal/site constraints - these factors relate to the environment within which the device will operate.
- Coach constraints - these factors identify the specific constraints associated with the coach entrance/stairwell for various coach designs. In addition, the feasibility of minor modifications to the coach within the entrance/stairwell are investigated.
- Operator constraints - are factors which relate to the operator's capabilities and availability to perform the necessary operations required to deploy a station based lift device.
- User constraints - are factors which specifically relate to potential candidate users for which the station based lift device is intended.

5.1 Terminal/Site Constraints

Knowledge of the environment in which a potential station based lift device will operate is fundamental to the overall reliability and ultimately the successfulness of the device. To gain a thorough understanding of the device's operating environment to which it will be subjected, a number of field trips were made to bus terminals within the Quebec City-Windsor Corridor, namely Montreal, Ottawa, Toronto and London. This corridor had been previously selected for the demonstration phase of the initial work plan.

The specific relevant information gathered relates to constraints associated with the platform, terminal building, the availability of personnel and the general procedures currently in place at the terminals visited. This information has been presented in Table 2 and is discussed further in the following sections.

TABLE 2 : INVENTORY OF BUS TERMINAL CONSTRAINTS

TERMINAL	OTTAWA	TORONTO	LONDON	MONTREAL
SITE DATA				
PLATFORMS				
. Number	14 Passenger Platforms 3 Cargo Platforms Generally 12 platforms are used for outbound buses and 2 are used for arrivals	9 Platforms used for intercity buses at Bay St. Commuter type carriers use 9 platforms at Elizabeth St. Terminal (GO, Etc.)	8 Platforms	23 Passenger Platforms 6 Cargo Platforms Cargo platforms are used for arrivals
. AC Power	Yes, Platforms 4 and 5	Yes, recently grounded, one location near Platform 1	Yes, two near platforms	Yes, at regular intervals
. Surface	Concrete	Smooth concrete sidewalks with brick carriageways for bus stalls	Concrete	Concrete
. Curb Height	15 cm	No curbs	No curbs (portable step)	11 cm
. Slope	Nil	Not uniform, brick carriageway varies	Very gradual, (provides drainage to centre of lot)	Very gradual, (due to age, settlement and cracking)
. Obstructions	Barricades exist primarily at boarding locations	Barricades exist at some platform locations	None	Barricades exist at several platform locations
TERMINAL				
. Door Width	90 cm doors (double)	75 cm doors (double) Baggage door - 100 cm	105 cm doorway	90 cm doors (double)
. Storage	Inside (cargo area)	Inside (baggage area)	Inside (baggage area)	Currently unavailable

TABLE 2 : INVENTORY OF BUS TERMINAL CONSTRAINTS (Continued)

TERMINAL	OTTAWA	TORONTO	LONDON	MONTREAL
SITE DATA				
PERSONNEL	Security personnel are responsible for providing assistance to passengers as required. Bus Drivers may be involved inside the bus	Security personnel often provide assistance to the elderly, (no physical exertion required). However the Terminal Supervisor/ Manager physically aid handicapped onto the bus Bus drivers would not be involved	Terminal employee (no security) Bus Drivers would not be involved.	Security personnel are responsible for providing assistance to passengers as required. Bus Drivers would not be involved
PROCEDURES				
. Reservations	Usually 24 hr notice and a form is completed indicating departure time and disability. A communications link exists to forward information regarding incoming passengers.	Usually notified the day before. A communications link exists to forward information regarding incoming passengers.	Usually 24 hr notice. A communications link. exists to forward information regarding incoming passengers.	Passengers call before leaving home to ensure someone is available to provide assistance at the terminal. A communications link exists to forward information regarding incoming passengers.
. Preboarding	Yes. Preboard at the arrivals platform - no barriers, parcels are also loaded at this location before the bus proceeds to designated departure gate.	Yes, for elderly. Reassign bus to platform 1b, near baggage area in large open space. Conflicts may exist with other buses.	No, has not been required. Prefer to use platform near the baggage area.	Yes, like to use preboarding. Preboard at the arrivals platform - no barriers, parcels are also loaded at this location before the bus proceeds to designated departure gate.
GENERAL COMMENTS	Kingston Chair difficult to maneuover (boom). Coach generally serviced within ½ hour.	Kingston Chair long, slow process. Still had to physically transfer persons to the device. Buses in and out in 20 min. at this terminal.	Kingston Chair large and clumsy. Currently have a Washington Chair available for use.	Did not use the Kingston Chair. Very little space inside the bus to move around.

5.1.1 Platforms

Platforms used for bus arrivals and departures can be categorized into two distinct types - those which are raised above the level of the bus carriageway (curbs are present) and those which are located at the same level of the bus carriageway (no curb present).

Platforms which are raised above the level of the coach carriageway generally exhibit a saw-tooth layout (Photo 2).

The staggering of buses in this fashion maximizes the number of buses which can be accommodated along a single terminal face while also providing sufficient space between adjacent buses to allow for passengers to queue prior to boarding. In addition, the outgoing platforms (departures) are generally equipped with barriers (Photo 3) which are designed to provide passenger guidance and produce an orderly flow of passengers into the coach.

Those terminals where the platform is located at the same level as the coach carriageway would exhibit the greatest height differential between the elevation of the platform and the coach floor (see Photo 4).

It is important that the station based lift device be able to be manoeuvred from its storage area to a location adjacent to the bus loading door and then be able to be firmly immobilized during its operation. Given this scenario, very specific information with respect to the platform surface and slope was gathered and is presented in Table 2. While flat level concrete surface platforms were by far the most prevalent, considerable deterioration (cracking and breaks in the concrete) was observed. In addition, the design of a station based lift device must consider the various elements such as salt/sand/snow which may, from time to time, be present on these platforms.

5.1.2 Terminal Building

Consideration has been given to providing a safe sheltered area where the proposed station based lift device may be stored when not in operation. Its typical infrequent use would suggest a location somewhat removed from the day-to-day operations while sufficiently close to the platform area to minimize the advance notification required to transport and set up the device on a platform when requested.

Terminal operators generally felt an interior location inside the terminal building such as their baggage area would be the preferable storage area. Consequently, transporting the device from its place of storage to the platform area will require negotiating various surfaces in addition to a number of doorways. The minimum doorway clearance encountered at those sites investigated was a 100 cm doorway to a baggage area. Most doorways consisted of 90 cm double doors (180 cm open clearance).

Photo 2 - Montreal Terminal - Raised Platform

Photo 3 - Ottawa Terminal - Barriers located at outbound platforms

Photo 4 - Toronto Terminal - Platform and coach are located at the same level (no curbs)

5.1.3 Personnel

Currently, a number of terminals make use of their security personnel to provide assistance to passengers as required. These responsibilities are typically covered in their general contract of services. In addition, based on discussions with terminal operators, it was considered inappropriate to assume bus drivers would be available to assist in boarding/deboarding passengers.

In either case, there is concern regarding the increasing risks of injury to the passenger or the persons responsible for providing assistance. It is therefore important that the physical exertion required by those assigned to assist a passenger transfer be minimized. This will be achieved primarily by developing a device which makes provisions for standard mobility aids and does not require physical action on the part of the passenger which lie outside their capabilities (i.e., transferring from a seat height lower than that which they are transferring into, etc.).

5.1.4 General Procedures

Users of the station based lift device will in all likelihood be required to provide prior notification (reservations) to the coach line. While some potential passengers may object to this and one can sympathize with this in principle, it is clear that the degree of mobility or immobility of a passenger determines both the level of effort (number of staff) and equipment which may be required to board the passenger. Prior notification allows the arrangement of this beforehand thereby avoiding disappointment and delays to the arriving passenger.

In general, notifications are currently required 24 hours in advance of desired departure time from mobility restricted passengers. In all likelihood, prenotifications of this nature would also be necessary should a station based lift device be used. Once this information has been received by terminal operators a communications network exists to transmit relevant information to the destination terminals, in order that it may make the appropriate arrangements for assisting the passengers in deboarding.

In addition to prenotification, passengers would be required to preboard. Preboarding for mobility impaired passengers would minimize the potential embarrassment felt by some passengers if boarding were to take place in the general loading area. Preboarding should occur at most terminals at the arrival platform since barriers do not exist at these platforms thereby providing maximum available manoeuvring space for a station based lift device.

5.1.5 Implications

A summary of the constraints imposed by intercity bus terminals and their associated implications are contained in Table 3. These are primarily directed towards potential station-based lift devices which can be moved about the terminal and platform areas.

5.2 Vehicle Constraints

The study has focused its efforts on the Motor Coach Industries model "MC9" and the Prevost Car Inc. model "Marathon/Mirage", since these two coaches represent the majority of coaches currently in use within the intercity bus industry.

In general terms, a station based lift device would operate from the terminal platform area and be capable of transporting mobility disabled persons from the platform level adjacent to the coach to the most frontward seats immediately inside the doorway of the coach at the same elevation as the coach seat area. The device would also be capable of the reverse (deboarding) operation as well. Some physical effort by the passenger or an attendant would be required to transfer laterally onto the coach seat from the station based lift device. To facilitate this transfer from the device to the seat, adequate manoeuvring space must be available inside the coach.

In addition to the manoeuvring space within the coach, several other vehicle dimensions have an influence on the development of a viable station based lift device. These dimensions are tabulated in Table 4 and are illustrated in Figure 2.

In general, the narrow dimensions of the stairwell, aisle and landing platform prohibits the possibility of the passenger remaining in a standard wheelchair. The passenger could be transferred from their personal wheelchair to a fixed chair (part of a station based lift device) or a narrow wheelchair, taken into the bus and then transferred to a regular seat. In all likelihood it will be necessary to assign the front seats to passengers using the station based lift device.

A typical boarding device would require the area next to the driver's seat for transferring (loading/unloading) passengers. This area is very restricted, typically ranging from 46 by 66 cm to 91 by 68 cm. Based on previous studies of spatial requirements for handicapped persons, an area equal to 355 square centimeters is required to execute a ninety degree turn in a standard wheelchair; however, in the seated position (chair not included), a person only requires a 1/4 circle radius of 91 centimetres. Sufficient space therefore is not readily available on the landing platform next to the driver's seat. This constraint could be minimized, if passengers were boarded in a forward facing direction to a location just at the edge of the landing area. The

TABLE 3 : BUS TERMINAL CONSTRAINTS AND THEIR IMPLICATIONS

	SITE FINDINGS	IMPLICATIONS
SITE DATA		
PLATFORMS		
. Number	Some operations segregate arrivals and departures by platforms.	
. AC Power	Generally available, not always at convenient locations.	Desirable to have a device which is self-powered and/or can make use of the on-board bus power
. Surface	All sites are essentially concrete surfaces, with varying surface textures.	Device should be designed to provide skid resistance on various concrete surfaces.
. Curb Height	Curb heights vary from 0 to 15 cm.	Device should be capable of accommodating varying curb heights (0 to 30 cm).
. Slope	No significant ground slopes.	Device should be capable of accommodating ground slopes between 0 to 2 percent.
. Obstructions	Barricades are present at most terminals and would restrict the use of any boarding device.	Consequently, preboarding at the arrival location and/or designated area would alleviate the problem.
TERMINAL		
. Door Width	Door widths vary - minimum 100 cm for a baggage area where a suitable device would likely be stored.	Nominal device width should be approximately 90 cm or less.
. Storage	Baggage areas appear to the most suitable storage areas.	Device should be capable of being stored in a sheltered location either on the platform or in the baggage room.
PERSONNEL	In general, security personnel are responsible for assisting the elderly and handicapped passengers. Bus drivers do not participate in this function.	It would be desirable to design the device so that one person could: manoeuvre, position, assist the passenger, transfer the passenger, and seat the passenger vice versa. Staff designated to carry out this role should be trained to handle the physically disabled.
PROCEDURES		
. Reservations	Generally a reservation/pre-notification system is in place and communications link between terminals currently exist.	It is expected these requirements will be maintained.
. Preboarding	Preboarding is widely used.	It appears likely that preboarding would be required to make the device a viable operation.

NOTE: These constraints are directed towards station based lift devices which are intended to be moved about within the terminal and platform areas. Many of these constraints would not be applicable to rigid or fixed (stationary) devices.

TABLE 4

SELECTED DIMENSIONS FOR MCI AND PREVOST INTERCITY COACH

Vehicle Attribute	DIMENSIONS	
	Motor Coach Industries MC9	PREVOST Marathon/Mirage
Landing platform at driver's seat to ground level	106 cm (vertical)	81 cm (vertical)
Number of steps to landing platform	3	2
Landing platform to level of passenger seats	15 cm (vertical) and ramped aisle	42 cm (vertical) and 2 steps
Stairwell width	66 cm (horizontal)	68 cm (horizontal)
Minimum width available in stairwell	57 cm (horizontal)	57 cm (horizontal)
Landing platform size	46 cm x 66 cm	91 cm x 68 cm
Clearance between passenger seat coach floor level and top of door frame	128 cm	129 cm
First step to ground level	30-41 cm	38-42 cm
Clear aisle between passenger	35 cm	35 cm
Door opening angle	69°	64°

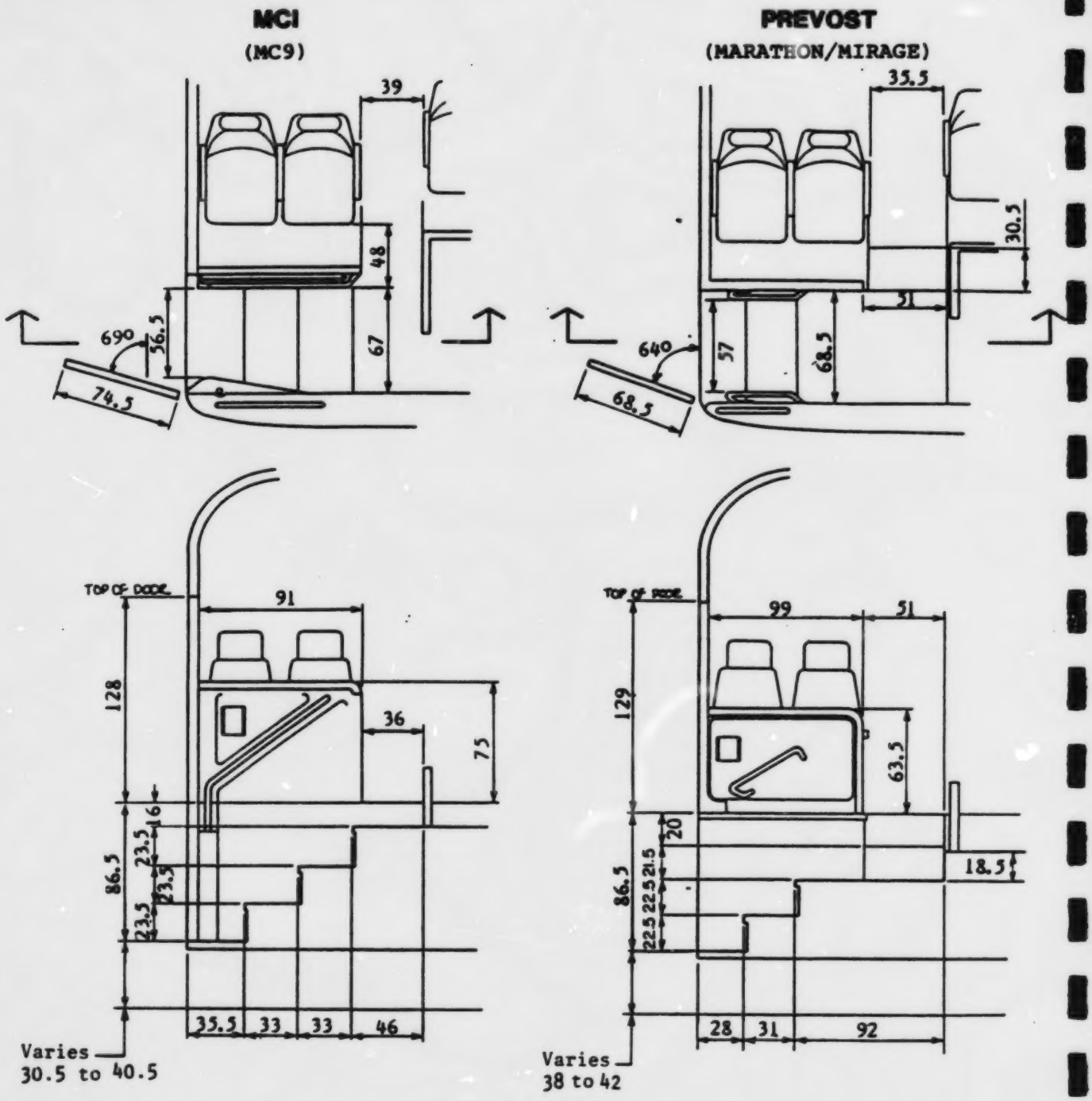

FIGURE 2

INTERIOR DIMENSIONS OF BUS ENTRANCE AREAS

(All Dimensions in Centimeters)

operator could then utilize the little space available more effectively to unload the passenger from the boarding device and transfer them to one of the designated front seats. Although boarding a passenger in the forward facing seated position can involve insufficient headroom, both bus models investigated, however, appear to have sufficient vertical clearance to carry out this process.

The safety bar/vanity panel and seat armrests create a barrier between the landing area and the front bus seats. Disabled passengers would currently have to be physically lifted over the fixed aisle armrest of seats to gain access to the coach seat. Folding and/or removeable armrests would significantly increase the ease of passenger transfer, with or without assistance. Folding and/or removable vanity panels could potentially reduce the confined space in the doorway and improve access to the front seats. Opportunities for modifying existing coaches to overcome these constraints exist and are discussed in section 5.3 of this report along with other simple options to improve the space availability within the stairwell.

Other important features of a station lift device are its capabilities to provide the required lifting height and depth, or transfer range for the various coach designs. Typical requirements are provided in Figure 2. In addition to the constraints imposed by the various coaches, platforms differ in their loading ramp/area design and/or height. Therefore, any boarding device design must easily accommodate a wide range of lifting heights and depths. In the case of a linear motion type device, such as one sloped along the stairwell, angular changes are required to accommodate various coaches and platforms. These angular changes would also necessitate an angular adjustment compensation mechanism to maintain a level seat position.

The minimal stairwell width (between handrails and/or interior trim panels) combined with the typical door opening angles make it very difficult to align a straight inline boarding device while maintaining adequate clearance for the device and/or passenger. Boarding devices which follow a slightly curved path would be much easier to align; however, the required technical complexity and associated cost would likely make it economically unfeasible. To limit the constraints associated with the door opening and lack of stairwell space, a number of simple bus modifications to increase the door opening angle and available stairwell width are investigated and discussed in section 5.3 of this report.

5.3 Potential Bus Modifications

This section of the report investigates limited bus modifications which have the potential of minimizing the current constraints imposed by intercity coaches. As a result, simpler, more efficient devices can be developed. Various levels of bus modifications are outlined including a discussion on the "no change" option. The primary modifications are directed toward aspects

which relate to the door opening, bus seats and safety bar/vanity panel. The work conducted in this section focuses on the most common models of intercity buses manufactured by Motor Coach Industries (MCI) and Prevost Car Incorporated which include the MC9 and the Marathon/Mirage models respectively.

Limited bus modifications for the purposes of this study have been defined as retrofits which may be carried out within a standard intercity bus repair depot without significant cost to the intercity bus operators. Modifications considered also had to be sufficiently simple in nature so that they could be easily integrated into the manufacturing process.

5.3.1 No Change Option

To fully appreciate the limitations of the existing coach constraints, one must be cognizant of space requirements to transfer passengers. As discussed earlier, in order to transfer a person to the coach seat from a seated position on a station based lift device the person must be rotated through ninety (90) degrees requiring a quarter circle of 91 centimetres radius([1]), not including space for the chair; however, there is currently insufficient space in the landing platform area beside the driver's seat, in either the MC9 or Marathon/Mirage buses to accomplish this. In addition, the bus coach stairwell and aisle are also extremely narrow and could not accommodate this manoeuvre. Therefore, the "no change" option severely restricts the development of an adequate design for a station based lift device.

5.3.2 Increased Door Opening Angle

The front loading doors on both the MCI and Prevost buses do not open fully (see Figure 2). While sufficient room exists for passengers to board/deboard, the limitation does constrain the space available to manoeuvre a station based lift device into place.

The door on the MCI bus when fully open, forms a 69 degree angle with the side of the coach and the door on the Prevost forms a 64 degree angle. Discussions with personnel at an intercity bus repair depot resulted in the suggestion that a small part in the door mechanism be replaced with a similar but longer part. This would effectively increase the opening angle of the door on both coach models.

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(1) Development of a Wheelchair Securement System Interim Report #1, TDC, February 1987.

Preliminary investigations of the MC9 and Marathon/Mirage models, identified the part which would require modification to be the lever arm located on the underside of the open/close handle mechanism. Both models use an over-centre design to hold the door rigidly in the open and closed positions. The lever arms are currently approximately 8 cm long, from pivot to pivot, which provides a maximum travel in the order of 15 cm to move the door through its full arc. Replacement or modification of this lever to provide a longer travel would effectively increase the door opening angle proportionately. In addition, the connecting arm which links the lever to the door would also require lengthening or the door would tend to over-close. These arms are typically adjustable within the required range; however, they could be very easily modified. An estimate of the time required to implement this modification is in the order of a few hours, given that new or modified components were available.

The increase in door opening angle which may be achieved on either bus model is primarily limited by the potential for physical interference from bus components. For example, on the Prevost bus, approximately 10 to 15 degrees could be added to the open door angle prior to developing interference between the door edge and the bumper extension. Removal or modification of the bumper extension may allow further door opening. On the MCI bus, only 5 to 10 degrees could be added before interference developed between the top hinge and the frame/door seal; however, relatively simple modifications to the hinge (i.e., curved or notched) or to the door seal could be made to further increase the door opening angle. Bumper interference is not a problem with the MCI bus.

In summary, the door angle modifications discussed are all fairly simple and inexpensive to achieve in terms of both components and installation time. The required level of modification and the associated costs may vary depending on specific requirements associated with different boarding devices; however, even the most simplistic modification could significantly improve accessibility for the station based lift device at ground level and could alleviate potential alignment problems in the stairwell.

5.3.3 Bus Seat Improvements

When transferring a mobility impaired passenger from the station based lift chair to a bus seat, the aisle side armrest of the bus seat can act as a barrier between the passenger and the seat. It would therefore appear advantageous to equip the chair with a removable or hinged armrest similar to many aircraft seats to minimize the level of effort associated with the transfer.

The armrests on both the MC9 and Marathon/Mirage buses are currently integral portions of the seat frame. These armrests would have to be removed and new ones designed and fabricated. A removable armrest that attaches to the side of the seat would be the simplest to design and retrofit

to existing buses and parts of the original armrests could easily be incorporated into the new design. The armrest may be designed to fit into a slot or bracket located on the side of the seat. Another approach for the design of the armrest may incorporate a hinge located on the side of the back rest of the seat; however, this would be somewhat more complicated and costly to design and fabricate than a removable unit. If an "off-the-shelf" armrest, complete with hinge could be supplied at a reasonable cost, perhaps from a manufacturer of airline seats, then this option could be given serious consideration.

Considerable interest has recently been expressed with respect to hinged armrests from manufacturers. These manufacturers are investigating various ways of incorporating accessible armrests into the design of new bus seats.

In addition, the narrow width of the stairwell and aisle (between armrests) dictate the use of coach seats located immediately adjacent to the stairwell. Regardless of direction (forward or rearward facing) of passenger boarding, transfer to both left or right front bus seats would be possible. For the case of forward boarding, limited counter-clockwise rotation of the passenger would be necessary to directly face the left seat; although, the driver's area panel (behind the seat) would be somewhat obstructive and the passenger would also require a full 180° rotation before final placement in the seat.

The situation is almost identical, but reversed, for the case of rearward facing boarding. Limited rotation of the passenger would be required in the clockwise direction and the safety bar/vanity panel in front of the right side seat would be very obstructive.

5.3.4 Safety Bar/Panel Removal

An additional modification which has been investigated is the removal of the safety bar/vanity panel. This modification appears to be a very cost effective method to increase the overall space available from which to provide assistance to a transferring passenger once inside the bus and in addition, would provide barrier free access to the right front seats.

The safety bar/vanity panel configuration in the Prevost bus is a relatively simple design as shown in Figure 3(i). The options discussed in the following sections are not intended to cover all design modification options but rather to indicate, conceptually, the potential for safety bar/vanity panel modifications.

The safety bar on the Prevost bus is bolted to the wall and floor with small brackets. The panel is held in place by screws in four locations, two on the wall and two on the safety bar post. There are several design modifications which would allow the safety bar/vanity panel to be removeable. The safety

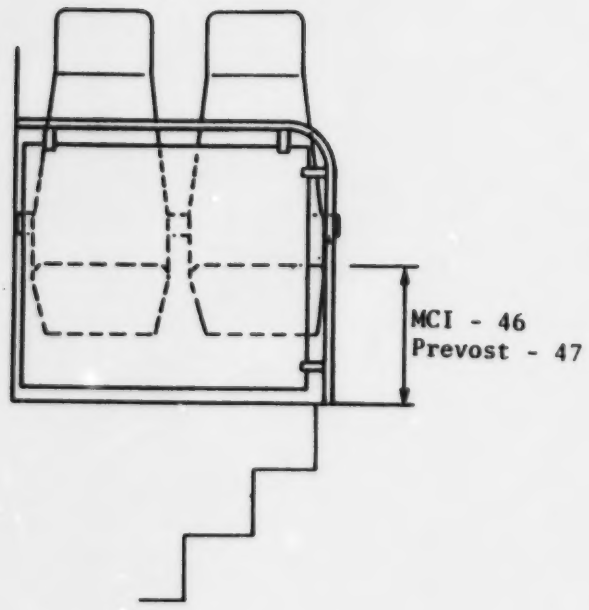
bar could be replaced by a fixed post and removeable cross bar as shown in Figure 3(ii). The panel would remain unchanged except that it would attach to the cross bar and pin into the floor instead of being screwed onto the post and walls.

Figure 3(iii) depicts another possible design option in which the cross bar, vanity panel and post are all removeable as a unit. In this design, it is likely that the original safety bar could be used as well as the original panel.

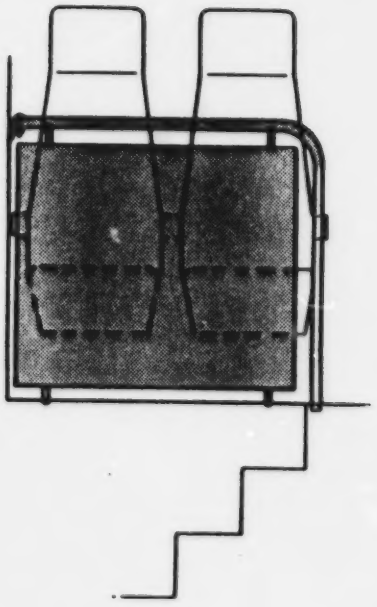
The safety bar/vanity panel design for the MC9 coach is similar to the Prevost design but slightly more complex. The panel is made of molded fibreglass and is held in place on the floor by a steel molding screwed into the floor. It is also secured to the post and bus wall by a metal molding that does not detach readily. In addition, the left hand stairwell railing presents some constraints. The bottom and top ends of the railing are attached to the stairwell and vanity panel, respectively. This makes removal of the panel quite difficult without also modifying the railing. One option would be to remove the existing safety bar/vanity panel and install a new design, similar to that shown in Figure 3(ii). The railing would require some extending to attach it to the top of the safety bar/vanity panel post. The post would not likely be removeable in this design. If the railing were replaced with a smaller unit such as that on the Prevost bus, then a design similar to the one in Figure 3(iii) may be used, where the railing length could be contained within the area of the panel.

On both buses investigated, a fold down vanity panel could bridge the gap of the stairwell allowing a passenger to be wheeled straight in at the same level as the coach floor. The available headroom for this operation between the seated mobility impaired passenger and the top of the coach doorway is approximately 130 cm as shown in Figure 2. The seated heights of Canadian adults range from 80 to 90 cm and the approximate seat heights of the MCI and Prevost buses are shown in Figure 3 (76 cm). From this information, it has been determined that a 130 centimetre vertical opening will only accommodate a few adult males and most adult females below the 50th percentile.

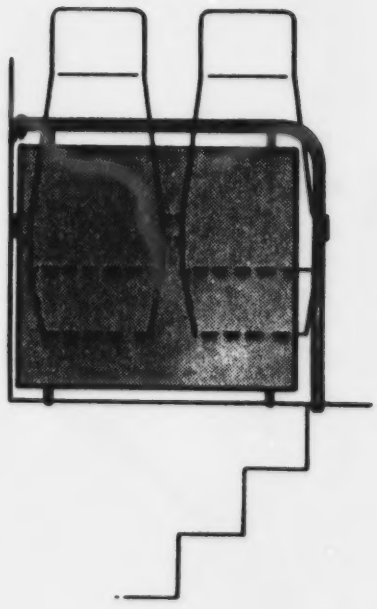
Ideally, several centimetres of vertical clearance above the passenger's head are desirable to visually portray a secure feeling to the passenger and to allow flexibility for eventuality such as hats, etc. A seat height on the lift device of 46 cm should be maintained to facilitate an easy transfer once inside at floor level; however, passengers, particularly the handicapped, tend to slouch in the seated position which could provide as much as 4 cm of extra clearance. These factors considered, the 130 cm clearance is simply not large enough to accommodate the majority of anticipated passengers when a fold down vanity panel is used. Since it is desirable to maintain the passenger



(i) The Existing Design of Safety Bar/Vanity Panel on the Prevost Bus



(ii) A Design for a Removable Cross-Bar and Vanity Panel



(iii) A Design for a Removable Safety Bar/Vanity Panel

FIGURE 3
REMOVABLE VANITY PANELS

at a seated height similar to that of the bus seat for ease in transferring and to provide a landing area at normal bus floor level for manoeuvring, the device would have to incorporate a variable height seat or reclining/tilting feature to provide adequate vertical headroom clearance.

The fold down panel could also incorporate a variable height feature; however, this would not likely constitute a simple and inexpensive modification to the bus. Regardless of the overall design approach, any fold down panel would likely require a totally new design. The panel would have to be greatly strengthened to hold the necessary loads (as per CAN3-D409-M84) for ramps. Both a hinge on the floor attached to the vanity panel and a bracket on the opposite stairwell wall for the panel to lock into would be required. The stairwell wall also requires strengthening in order to provide the necessary support for the bracket.

Figure 2 illustrates the elevation difference between a hinged vanity panel and the normal bus landing for both bus models. The vanity panel floor section would be approximately 16.5 cm and 42 cm above the landing area floor on the MCI and Prevost models, respectively. These elevation differences, particularly on the Prevost, would necessitate a small railing along the edge of the vanity panel floor when hinged down.

Other options to improve the level of safety include: a two-piece vanity panel that folds twice, once to bridge the stairwell gap and a second time to bridge the elevation gap over the landing area; a temporary floor raiser added to the Prevost model to minimize the elevation difference; a second fold down panel incorporated into the driver's side of the landing wall to bridge the landing area/vanity panel gap; or vanity panels modified in such a way that they hinge downward and drop to an elevation below the normal bus floor level, thus minimizing the elevation difference from the vanity panel floor to the landing area, but adding another up to the normal bus floor level. This latter option would greatly assist during passenger boarding due to the increased headroom as well as providing a reasonably good working surface for the operator; however, assuming a lift device seat height in the order of 46 cm (similar to the bus seats), the transfer operation would involve vertically lifting the passengers in proportion to the amount the panel folds down below normal floor level.

In summary, modifications to the safety bar/vanity panel can be easily achieved and incorporated at a relatively low cost. Simple removal or folding modifications to the safety bar/vanity panel are the easiest and most cost-effective method to obtain a large clear area for passenger boarding. The folding panel approach significantly limits the type of boarding device which can be accommodated since the stairwell area would no longer be available, headroom is severely restricted and/or significant elevation differences would exist between the bus floor and panel floor for transfer operations.

Regardless of the basic concept, bus modifications would have to be considered in conjunction with the specific needs or requirements of a proposed lift device and be developed for adequate safety, function and cost effectiveness as an integral component of the overall boarding system.

5.4 Operator Constraints

Currently, intercity coach lines are attempting to provide, to the extent possible, barrier free transportation. In many cases, this means providing physical assistance to individual travelers (particularly the disabled population). This assistance is generally provided by those individuals responsible for security at the individual terminals, persons who in many cases have not been afforded the required training in techniques to aid persons with disabilities.

Consequently, the development of a device to aid disabled persons boarding intercity buses would minimize the exposure to physical injury to either the person providing assistance or the person being assisted.

Generally, the acceptable level of assistance would be the lifting (on the part of the operator), of a 90 kilogram person, approximately 5-8 cm for about 5-10 seconds (comparable to lifting a 90 kilogram person and sliding him or her over to a seat).

In addition to the level of effort required to transfer a potential candidate user, it is also important to identify the capabilities of the individual responsible for retrieving the proposed lift device from a storage area within the terminal building. Acceptable levels of effort required to mobilize a manually propelled device should require less than a 130-180 N force over a period not greater than four minutes. Lifting forces required should not exceed 130 N. These acceptable levels of effort have been determined based on an assessment of the capabilities of a reasonable cross-section of the adult population including both men and women.

5.5 User Constraints

The identification of potential candidate users of a station-based lift device has been based on several factors, including: an inability to negotiate stairs through the front door of the bus, sufficient storage space for the passenger's mobility aids, the passenger's ability to negotiate the bus aisle and the space requirements to properly transfer into and out of a seat.

As previously described in Section 4.0 - Candidate User Groups, the primary criteria which identify candidate user groups are that the potential users be capable of remaining seated (unrestrained in a standard bus seat) for the duration of the trip and be capable of travelling with compact light-weight mobility aids. Although this definition does not provide completely barrier

free transportation on intercity buses, it does represent a sufficiently large component of the mobility disadvantaged population to warrant serious consideration by intercity bus operators.

To gain insight with respect to the acceptability of a station based lift device to aid boarding and deboarding of intercity buses, representatives of the Canadian Paraplegic Association in Ottawa and Toronto were contacted. Generally, the comments were positive given the capabilities and expectations of the proposed device. Those contacted were given brief descriptions of the objectives of the proposed device and the concensus was that many parapalegics would be well suited as potential users while most quadrapalegics would not be as well suited. While comments were received as part of this activity, no major constraints were identified through discussions with members of the user groups.

6.0 RECOMMENDED DESIGN CRITERIA

Design criteria for a station based lift device are required in order to avoid potential problem areas as discussed in the "Problem Areas - Transfer Chair Case Study" (Section 3.0); to satisfy the needs of the candidate user groups (Section 4.0) and to take into account the various factors which can influence the operation of the device (Section 5.0). The availability of such criteria would also allow the evaluation of various station based lift designs based on a recognized set of parameters given the relative weights associated with each of the parameters.

In general, design criteria are not easily isolated: they typically interact and in some cases conflict with each other. Consequently, trade-offs are required to establish the overall design criteria. Some criteria involve quantifiable factors such as relative cost, performance, efficiency, reliability and compatibility with existing systems, but others are more subjective, including: safety, quality, comfort, simplicity and adaptability. In short, the design criteria provide a basis for choosing the preferred solution among alternative solutions and provide guidelines for optimizing various alternatives.

6.1 Formulation of Design Criteria

The design criteria formulated reflect the experience gained through testing of the "Kingston Transfer Chair". Seven major categories have been established for which criteria have been formulated, namely:

- exterior appearance
- device/coach interface
- passenger safety/comfort
- functional adequacy
- accessibility
- technical requirements
- control system.

Each of the seven categories of design criteria are briefly described in the following paragraphs:

Exterior Appearance. The exterior appearance is an important overall design element. The device should convey a safe visually appealing image to ensure acceptance on the part of potential users. Designs which may be obtrusive and/or portray the device as either "construction equipment" or "dedicated handicapped equipment" should be avoided.

Device/Coach Interface. A positive linkage between the proposed station lift device and the bus coach must be provided. While it is understood that very little space exists (narrow stairwells), every attempt must be made to ensure the safety and the relative ease with which this linkage is carried out. It is important to note that, the operator of the proposed lift device (based on very infrequent use) will be expected to position the device properly without considerable training being provided. Consequently, design characteristics associated with this element have been formulated to address these concerns.

Passenger Safety/Comfort. Issues such as the provision of armrests, footrests, overall passenger protection and various ergonomic considerations have been included in this category.

Functional Adequacy. A vital element in the evaluation of any device is "how well does it meet the needs of the operator and/or user?" This design element has been structured to address those concerns which relate to the user/operator. A station based lift device is assumed to be a device which is generally operated by one person, and is easily moved about the terminal environment while requiring limited physical effort. Consequently, design criteria developed within this section focus on personnel requirements, manoeuvrability and the level of effort required to move and position the station-based lift device.

Accessibility. To ensure a high level of accessibility, features which tend to prohibit/restrict various user groups from using the station based lift device should be avoided. In particular the design of the seat, the area available for transferring passengers and the total time to carry out the overall process are factors to be considered.

Technical Requirements. Design criteria have been established with respect to the overall technical performance of the device. Features of particular importance are lift/chair speed, power requirements, design load and design life.

Control System. The control system requires considerable attention to ensure all ergonomic and functional related aspects are considered. Features such as pressure activated switches and automatic reset controls are addressed under the control system category.

For each of the seven broad categories of design criteria, specific criteria associated with each of these have been developed. These criteria provide additional details on the particular design feature and/or factor as it relates to each of the broad categories. Table 5 summarizes this information and indicates both the desirable (ideal) standard and the minimum acceptable

TABLE 5
STATION BASED LIFT DEVICE DESIGN CRITERIA

		SUGGESTED DESIGN CRITERIA	
		IDEAL	MINIMUM ACCEPTABLE
(1)	**Exterior Appearance**		
	(a) Obtrusiveness	. Blends into architecture and vehicle environment.	
	(b) Form	. Integration of colours, surface textures and structural components.	
	(c) Protrusions	. No sharp corners or overhanging structures.	. Corners or overhanging structures are mitigated.
(2)	**Device/Coach Interface**		
	(a) Compatibility to various coach designs	. Current intercity bus fleet.	. MCI-"MC9", Prevost - "Marathon/Mirage".
	(b) Requirements for bus modifications	. None.	. Minor coach modifications limited to coach entrance/stairwell area components.
	(c) Level of effort required to deploy the device	. 2 minutes - minimal effort with clear visible reference points for positioning device in the stairwell.	. 3 minutes - medium effort with reference points provided to position device.
	(d) Physical link	. Positive link between coach and proposed device.	. High friction connection.
	(e) Visual cues for positioning device	. Provide high target value under all lighting and weather conditions.	. Provide clear target under most lighting and weather conditions.
	(f) Damage risk to coach during interfacing process	. Provide complete protection to coach doorway and stairwell components during use.	. Minimal risk for limited damage to coach doorway and stairwell components during use.

TABLE 5

STATION BASED LIFT DEVICE DESIGN CRITERIA (Continued)

		SUGGESTED DESIGN CRITERIA	
		IDEAL	MINIMUM ACCEPTABLE
(3)	**Passenger Safety/Comfort**		
	(a) Passenger protection	. No exposure (of limbs and/or clothing) to moving or rotating parts. Complete body support to avoid contact with coach during ascent/descent. . Provide comfort/safety belt to insure passenger is properly positioned in seat.	
	(b) Passenger comfort	. All components of the device which physically come in contact with the passenger should be covered or padded and be warm to touch.	. Major components which come in contact with the passenger should be padded.
	(c) Level of effort required for transfer	. Minimal (unassisted).	. Medium - 1 person assisting.
	(d) Seat comfort	. Padded with medium density foam to avoid "bottoming". . Armrest padding to be firm. . Measure 90 cm across/40 cm deep with a seat backrest angle of 105-110°, a seat angle of 5-10° and an armrest height of 18-20 cm above seat height.	. Padded seat, measure 40 cm across and deep and provide stable armrest.
	(e) Armrests	. Armrests should extend beyond the front of the chair to aid those transferring passengers with upper body strength. . Armrests should be stable and individually support 45 kg.	
	(f) Footrest	. Lower limbs should be supported under the soles, on back of heels and laterally, noting a high proportion of potential users have little control over their lower limbs. . Footrest should support 115 kg passenger and be located as close to the ground as possible during the transfer into the chair.	. Footrest should support 100 kg passenger.
	(g) Ascending and decending acceleration	. Gradual acceleration (not to exceed 90 cm/sec^2).	
	(h) Vibration of passenger seat	. No significant vibration.	. Minimal vibration.
	(i) Noise levels during operation	. Comparable to light traffic at 15 m, may be considered intrusive (60dB).	. Comparable to highway traffic at 15 m, telephone difficult to use (70dB).

TABLE 5

STATION BASED LIFT DEVICE DESIGN CRITERIA (Continued)

		SUGGESTED DESIGN CRITERIA	
		IDEAL	MINIMUM ACCEPTABLE
(4)	**Functional Adequacy**		
(a)	Personnel Requirements to manoeuvre, position and assist the passenger, transfer and seat the passenger.	. Maximum one person.	. Maximum 2 persons.
(b)	Preboarding	. Not required.	. Preboarding required but in a designated area.
(c)	Ease with which it can be moved about the terminal (operating environment)	. Accommodate 0-2% sloping platform and 0-30 cm curb height and varying concrete/asphalt surface.	. Accommodate varying 0-1% sloping platforms and 0-15 cm curb height and concrete surfaces.
(d)	Effort/time required to transport device from storage to the platform area	. A sustained push/pulling/lifting force of less than 130 N for no longer than 2 minutes duration (transport time less than 3 minutes).	. A sustained push/pulling/lifting force of less than 180 N for no longer than 4 minutes duration (transport time less than 8 minutes).
(e)	Aids for transporting device	. Adjustable height from 85 to 100 cm providing good grip and friction qualities able to accommodate 95th percentile male hand with gloves.	. Fixed height between 85-100 cm with good grip and able to accommodate 95th percentile male hand with gloves.
(f)	Centre of gravity	. Shall be located to minimize the propensity to overturn while sufficiently high to minimize effort required to move the device when force is applied to the handles.	. No overturning potential under normal operation.
(g)	Width (while transporting)	. Maximum 90 cm	. Maximum 100 cm
(h)	Device positioning	. Positive immobilizing position required for device on platform surface and on coach floor landing, adjustable according to coach type. . If foot controlled, foot remains on floor and applies a maximum force of 3 N.. . When hand controlled, lever may travel through a maximum of 15° angle with a maximum force of 50 N.	
(i)	Portability	. Stowed in the bus baggage area.	. Limited to remaining at the terminal.

TABLE 5

STATION BASED LIFT DEVICE DESIGN CRITERIA (Continued)

		SUGGESTED DESIGN CRITERIA	
		IDEAL	MINIMUM ACCEPTABLE
(5)	**Accessibility**		
	(a) Seat design	. Seat height adjustable 35-50 cm. . Footrest to seat separation adjustable: 35-50 cm. . Stable chair, footrest and supporting removable armrest. . Minimal physical contact between passenger and operator while adjustments are carried out.	. Seat height (45 cm). . Footrest to seat separation (45 cm). . Stable chair, footrest and supporting removable armrest.
	(b) Device size/area remaining for passengers	. 80 x 120 cm is required adjacent to the lift device on the platform to ensure passengers may adequately perform the transfer into the seat.	
	(c) Transfer time from when the passenger begins to transfer into device chair until the passenger is seated into the coach	. Less than 2 to 3 minutes.	. Less than 5 minutes.
(6)	**Technical Requirements**		
	(a) Power	. Either self contained source or obtained from coach.	. Self contained, obtained from coach or 110 AC from terminal building.
	(b) Manual override	. Device should be equipped with an easily accessible manual override system requiring minimum effort by the operator. (Two minute execution time.)	. Device should be equipped with an easily accessible manual override system requiring minimum effort by the operator. (Five minute execution time.)
	(c) Lift/chair speed	. Infinitely variable from 0 to 7.8 metres per minute.	. Variable, 1.2 meters per minute increments, maximum 7.8 metres per minute.
	(d) Selection of components	. Exclusive use of standard off the shelf components/hardware.	. Maximum use of standard off the shelf component/hardware.
	(e) Pay load	. 115 kg	. 100 kg
	(f) Design load	. 575 kg, i.e., safety factor of 5.	. 400 kg, i.e., safety factor of 4.
	(g) Design life	. 1500 cycles minimum (5 years in service)	. 1000 cycles minimum (3 years in service)
	(h) Maintenance/Servicing	. Not required throughout design life.	. Service required twice a year. . Good access to all serviceable components.

TABLE 5

STATION BASED LIFT DEVICE DESIGN CRITERIA (Continued)

		SUGGESTED DESIGN CRITERIA	
		IDEAL	MINIMUM ACCEPTABLE
(7)	Control System		
	(a) Control system features	. Failsafe device - in the event of power failure, average descent speed less than 7.8 metres/minute. . Equipped with a device to prohibit operation when not properly immobilized and/or engaged. . Automatic reset control to reset all controls to the off position (when power is interrupted). . Automatic deceleration near the termination of up and down chair position.	
	(b) Function of control panel	. Movements of the seat/chair up/down with speed adjustment. . Stopping of seat/chair gradually. . Indicate operation status "on" or "off". . All controls to provide audio feedback (i.e., click).	. Adjustable speed on the control panel.
	(c) Location of controls	. If remote controlled it should be shock resistant material and sustain no damage or switch activation from a 1.5 m fall onto concrete surface. . Remote control unit should fit in one hand and be activated with same hand (either right or left) with or without gloves. . Fixed control panel should be located to ensure operator has unobstructed view of the entire operation and be mounted 100-110 cm at an angle of 0-15°.	
	(d) Information portrayed on controls	. Both official languages, using symbols and colours to clarify and highlight functions, with up control on the upper part of the panel and down on the lower part. . Provide illumination at night.	
	(e) Switch type	. Push buttons - 2.5 sq.cm area with maximum 32 mm fully depressed using a force of 1 to 8 N. . Barrier (lip) to prevent accidental activation of push buttons.	

standard associated with each criteria. It is important to understand that the recommended design criteria should not be perceived as inflexible rules but rather guidelines which provide a framework for the design and development of the sub-systems. In particular, this applies to standards which have been converted from the imperial system to the metric system.

The information contained in the design criteria reflect the need for a relatively simple device which can be transported, set up and used with reasonable levels of effort. Time requirements are also important considerations and the design criteria indicate the desirable (ideal) time requirements to deploy the station based lift device should be less than seven minutes. However, a station based lift device which requires considerable more time up to a maximum of 15 minutes would meet the minimum acceptable standard.

6.2 Weighting of Design Criteria

The weighting of design criteria as a function of their relative importance is a standard engineering practice which provides a structured means of comparison between the attributes of various designs.

The first step in this process is to weight each of the seven categories of design criteria as they relate to each other (assuming the total seven design elements represent 100 percent). The second step involves weighting of each individual criterion within the categories (assuming each of the individual criterion represent a percentage of the total category). The results of this process as applied to the transfer chair device are presented in Table 6.

TABLE 6 : WEIGHTING OF DESIGN CRITERIA

Design Element		Weighting
Exterior Appearance		5
(a) Obtrusiveness	30	
(b) Form	30	
(c) Protrusions	40	
	100%	

TABLE 6 : WEIGHTING OF DESIGN CRITERIA (Continued)

Design Element		Weighting	
Device/Coach Interface			10
(a)	Compatibility to various coach designs	20	
(b)	Requirements for bus modifications	20	
(c)	Level of effort required to deploy the device	20	
(d)	Physical link	15	
(e)	Visual cues for positioning device	10	
(f)	Damage risk to coach during interfacing process	15	
		100%	
(a)	Passenger protection	20	
(b)	Passenger comfort	10	
(c)	Level of effort required for transfer	15	
(d)	Seat comfort	10	
(e)	Armrests	10	
(f)	Footrests	5	
(g)	Ascending and descending acceleration	10	
(h)	Vibration of passenger seat	10	
(i)	Noise levels during operation	10	
		100%	

TABLE 6 : WEIGHTING OF DESIGN CRITERIA (Continued)

	Design Element	Weighting	
Functional Adequacy			15
(a)	Personnel requirements	15	
(b)	Preboarding	10	
(c)	Ease with which it can be moved about the terminal (operating environment)	15	
(d)	Effort/time required to transport device from storage to the platform area	10	
(e)	Aids for transporting device	10	
(f)	Centre of gravity	10	
(g)	Width (while transporting)	10	
(h)	Device positioning	10	
(i)	Portability	10	
		100%	
Accessibility			15
(a)	Seat design	35	
(b)	Device size/area remaining for passengers	30	
(c)	Transfer time from when the passenger begins to transfer into device chair until the passenger is seated into the coach	35	
		100%	

TABLE 6 : WEIGHTING OF DESIGN CRITERIA (Continued)

Design Element		Weighting	
Technical Requirements			20
(a)	Power	15	
(b)	Manual override	15	
(c)	Lift/chair speed	10	
(d)	Selection of components	10	
(e)	Pay load	10	
(f)	Design load	10	
(g)	Design life	10	
(h)	Maintenance/Servicing	20	
		100%	
Control System			10
(a)	Control system features	30	
(b)	Function of control panel	30	
(c)	Location of control panels	10	
(d)	Information portrayed on control panel	20	
(e)	Switch type located on control panel	10	
		100%	

6.3 Rating Alternative Designs

A number of rating (scoring) schemes may be applied to evaluate alternative designs. The scheme retained here applies a 0-10 rating. A "0" indicates complete failure to meet a criterion, a "5" indicates it is minimally acceptable, and a "10" identifies a criterion which has been fully achieved. This scheme allows for some objectivity on the part of the evaluation team should some alternatives be marginally more acceptable than others. Consequently a "6" and an "8" for example may be used to indicate marginal differences among alternatives.

The sample evaluation and scoring sheet which follows has been completed and indicate the scores for two alternative designs. This sample demonstrates the overall weighting scheme as it would be applied to the various design elements. In the two cases shown, each of the design elements are scored against the criteria (range 0-10) and then the weighting is applied. The sample scores for Exterior Appearance are 6500 for Alternative "A" and 5000 for Alternative "B". This scoring indicates for this design element that Alternative "A" achieves 25 percent more points than Alternative "B". This technique is applied for all design elements. The final score of approximately 75 500 for Alternative "A" and 67 500 for Alternative "B" suggests that Alternative "A", when rated against Alternative "B", is about 10 percent more desirable than Alternative "B". A blank evaluation form is presented in Appendix B for future use in evaluating alternative station based lift devices.

Some designs will be obviously inferior to others when measured against the design criteria and this will become apparent during the evaluation of the various station based lift concepts; however, some of the deficiencies, which do not unduly constrain the concept may be revised to improve the performance of the device while maintaining its feasibility.

In addition to the application of the recommended design criteria as set forth in this chapter, each of the various station based lift concepts must be further judged on:

- whether the potential benefits of the various sub-systems are proportional to the costs of providing them;
- whether or not the cost of the device corresponds to market constraints.

The cost implications associated with a station based lift device are important considerations and will guide the ultimate design of a feasible station based lift device.

While the production costs of a station based lift device are related to a number of factors, design life is paramount. The design life recommended as part of the design criteria indicate that the device should be capable of performing 1000 to 1500 cycles (which reflects an approximate 3 to 5 year life based on a sustained daily use). Reasonable production costs associated with a device of this nature would be in the order of $5,000 to $10,000.

TABLE 7

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(1)	Exterior Appearance			Score	Score
	(a) Obtrusiveness	. Blends into architecture and vehicle environment.		3 x (30) = 90	5 x (30) = 150
	(b) Form	. Integration of colours, surface textures and structural components.		8 x (30) = 240	5 x (30) = 150
	(c) Protrusions	. No sharp corners or overhanging structures.	. Corners or overhanging structures are mitigated.	8 x (40) = 320	5 x (40) = 200
				650 x (10)	500 x (10)
				6500	5000
(2)	Device/Coach Interface			Score	Score
	(a) Compatibility to various coach designs	. Current intercity bus fleet.	. MCI-"MC9", Prevost - "Marathon/Mirage".	8 x (20) = 160	5 x (20) = 100
	(b) Requirements for bus modifications	. None.	. Minor coach modifications limited to coach entrance/stairwell area components.	5 x (20) = 100	7 x (20) = 140
	(c) Level of effort required to deploy the device	. 2 minutes - minimal effort with clear visible reference points for positioning device in the stairwell.	. 3 minutes - medium effort with reference points provided to position device.	8 x (20) = 160	8 x (20) = 160
	(d) Physical link	. Positive link between coach and proposed device.	. High friction connection.	9 x (15) = 135	5 x (15) = 75
	(e) Visual cues for positioning device	. Provide high target value under all lighting and weather conditions.	. Provide clear target under most lighting and weather conditions.	9 x (10) = 90	5 x (10) = 50
	(f) Damage risk to coach during interfacing process	. Provide complete protection to coach doorway and stairwell components during use.	. Minimal risk for limited damage to coach doorway and stairwell components during use.	7 x (15) = 105	7 x (15) = 105
				750 x (10)	630 x (10)
				7500	6300

TABLE 7

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(3)	**Passenger Safety/Comfort**			Score	Score
	(a) Passenger protection	. No exposure (of limbs and/or clothing) to moving or rotating parts. Complete body support to avoid contact with coach during ascent/descent. . Provide comfort/safety belt to insure passenger is properly positioned in seat.		8 x (20) = 160	9 x (20) = 180
	(b) Passenger comfort	. All components of the device which physically come in contact with the passenger should be covered or padded and be warm to touch.	. Major components which come in contact with the passenger should be padded.	6 x (10) = 60	2 x (10) = 20
	(c) Level of effort required for transfer	. Minimal (unassisted).	. Medium - 1 person assisting.	8 x (15) = 120	8 x (15) = 120
	(d) Seat comfort	. Padded with medium density foam to avoid "bottoming". . Armrest padding to be firm. . Measure 90 cm across/40 cm deep with a seat backrest angle of 105-110°, a seat angle of 5-10° and an armrest height of 18-20 cm above seat height.	. Padded seat, measure 40 cm across and deep and provide stable armrest.	5 x (10) = 50	5 x (10) = 50
	(e) Armrests	. Armrests should extend beyond the front of the chair to aid those transferring passengers with upper body strength. . Armrests should be stable and individually support 45 kg.		8 x (10) = 80	5 x (10) = 50
	(f) Footrest	. Lower limbs should be supported under the soles, on back of heels and laterally, noting a high proportion of potential users have little control over their lower limbs. . Footrest should support 115 kg passenger and be located as close to the ground as possible during the transfer into the chair.	. Footrest should support 100 kg passenger.	5 x (5) = 25	5 x (5) = 25
	(g) Ascending and decending acceleration	. Gradual acceleration (not to exceed 90 cm/sec^2).		8 x (10) = 80	8 x (10) = 80
	(h) Vibration of passenger seat	. No significant vibration.	. Minimal vibration.	8 x (10) = 80	8 x (10) = 80
	(i) Noise levels during operation	. Comparable to light traffic at 15 m, may be considered intrusive (60dB).	. Comparable to highway traffic at 15 m, telephone difficult to use (70dB).	8 x (10) = 80	8 x (10) = 80
				735	655
				x (25)	x (25)
				18375	16375

TABLE 7

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES			
		IDEAL	MINIMUM ACCEPTABLE	"A"		"B"	
				Score		Score	
(v)	**Functional Adequacy**						
	(a) Personnel Requirements to manoeuvre, position and assist the passenger, transfer and seat the passenger.	. Maximum one person.	. Maximum 2 persons.	8 x (15) =	120	8 x (15) =	120
	(b) Preboarding	. Not required.	. Preboarding required but in a designated area.	8 x (10) =	80	5 x (10) =	50
	(c) Ease with which it can be moved about the terminal (operating environment)	. Accommodate 0-2% sloping platform and 0-30 cm curb height and varying concrete/asphalt surface.	. Accommodate varying 0-1% sloping platforms and 0-15 cm curb height and concrete surfaces.	5 x (15) =	75	5 x (15) =	75
	(d) Effort/time required to transport device from storage to the platform area	. A sustained push/pulling/lifting force of less than 130 N for no longer than 2 minutes duration (transport time less than 3 minutes).	. A sustained push/pulling/lifting force of less than 180 N for no longer than 4 minutes duration (transport time less than 8 minutes).	5 x (10) =	50	8 x (10) =	80
	(e) Aids for transporting device	. Adjustable height from 85 to 100 cm providing good grip and friction qualities able to accommodate 95th percentile male hand with gloves.	. Fixed height between 85-100 cm with good grip and able to accommodate 95th percentile male hand with gloves.	5 x (10) =	50	8 x (10) =	80
	(f) Centre of gravity	. Shall be located to minimize the propensity to overturn while sufficiently high to minimize effort required to move the device when force is applied to the handles.	. No overturning potential under normal operation.	8 x (10) =	80	8 x (10) =	80
	(g) Width (while transporting)	. Maximum 90 cm	. Maximum 100 cm	5 x (10) =	50	5 x (10) =	50
	(h) Device positioning	. Positive immobilizing position required for device on platform surface and on coach floor landing, adjustable according to coach type. . If foot controlled, foot remains on floor and applies a maximum force of 3 N. . When hand controlled, lever may travel through a maximum of 15° angle with a maximum force of 50 N.		8 x (10) =	80	5 x (10) =	50
	(i) Portability	. Stowed in the bus baggage area.	. Limited to remaining at the terminal.	5 x (10) =	50	5 x (10) =	50
					735 x (15)		635 x (15)
					11025		9525

TABLE 7

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(5)	**Accessibility**			Score	Score
	(a) Seat design	. Seat height adjustable 35-50 cm. . Footrest to seat separation adjustable: 35-50 cm. . Stable chair, footrest and supporting removable armrest. . Minimal physical contact between passenger and operator while adjustments are carried out.	. Seat height (45 cm). . Footrest to seat separation (45 cm). . Stable chair, footrest and supporting removable armrest.	5 x (35) = 175	5 x (35) = 175
	(b) Device size/area remaining for passengers	. 80 x 120 cm is required adjacent to the lift device on the platform to ensure passengers may adequately perform the transfer into the seat.		8 x (30) = 240	6 x (30) = 180
	(c) Transfer time from when the passenger begins to transfer into device chair until the passenger is seated into the coach	. Less than 2 to 3 minutes.	. Less than 5 minutes.	6 x (35) = 210	6 x (35) = 210
				625 x (15)	565 x (15)
				9375	8475
(6)	**Technical Requirements**			Score	Score
	(a) Power	. Either self contained source or obtained from coach.	. Self contained, obtained from coach or 110 AC from terminal building.	8 x (15) = 120	8 x (15) = 120
	(b) Manual override	. Device should be equipped with an easily accessible manual override system requiring minimum effort by the operator. (Two minute execution time.)	. Device should be equipped with an easily accessible manual override system requiring minimum effort by the operator. (Five minute execution time.)	5 x (15) = 75	5 x (15) = 75
	(c) Lift/chair speed	. Infinitely variable from 0 to 7.8 metres per minute.	. Variable, 1.2 meters per minute increments, maximum 7.8 metres per minute.		
	(d) Selection of components	. Exclusive use of standard off the shelf components/hardware.	. Maximum use of standard off the shelf component/hardware.	5 x (10) = 50	8 x (10) = 80
	(e) Pay load	. 115 kg	. 100 kg	8 x (10) = 80	5 x (10) = 50
	(f) Design load	. 575 kg, i.e., safety factor of 5.	. 400 kg, i.e., safety factor of 4.	9 x (10) = 90	9 x (10) = 90
	(g) Design life	. 1500 cycles minimum (5 years in service)	. 1000 cycles minimum (3 years in service)	10 x (10) = 100	10 x (10) = 100
	(h) Maintenance/Servicing	. Not required throughout design life.	. Service required twice a year. . Good access to all serviceable components.	10 x (20) = 200	10 x (20) = 200
				765 x (20)	765 x (20)
				15300	15300

TABLE 7

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(7)	Control System			Score	Score
	(a) Control system features	. Failsafe device - in the event of power failure, average descent speed less than 7.8 metres/minute. . Equipped with a device to prohibit operation when not properly immobilized and/or engaged. . Automatic reset control to reset all controls to the off position (when power is interrupted). . Automatic deceleration near the termination of up and down chair position.		7 x (30) = 210	7 x (30) = 210
	(b) Function of control panel	. Movements of the seat/chair up/down with speed adjustment. . Stopping of seat/chair gradually. . Indicate operation status "on" or "off". . All controls to provide audio feedback (i.e., click).	. Adjustable speed on the control panel.	8 x (30) = 240	7 x (30) = 210
	(c) Location of controls	. If remote controlled it should be shock resistant material and sustain no damage or switch activation from a 1.5 m fall onto concrete surface. . Remote control unit should fit in one hand and be activated with same hand (either right or left) with or without gloves. . Fixed control panel should be located to ensure operator has unobstructed view of the entire operation and be mounted 100-110 cm at an angle of 0-15°.		5 x (10) = 50	5 x (10) = 50
	(d) Information portrayed on controls	. Both official languages, using symbols and colours to clarify and highlight functions, with up control on the upper part of the panel and down on the lower part. . Provide illumination at night.		8 x (20) = 160	5 x (20) = 100
	(e) Switch type	. Push buttons - 2.5 sq.cm area with maximum 32 mm fully depressed using a force of 1 to 8 N. . Barrier (lip) to prevent accidental activation of push buttons.		8 x (10) = 80 740 x (10) 7400	8 x (10) = 80 630 x (10) 6300
			TOTAL ALL DESIGN CRITERIA (SUM OF SUB-TOTALS)	75475	67475

7.0 CONCLUSIONS

A review of the potential user groups which may benefit from the development of a station based lift device suggests that mobility impaired persons wishing to use such a device should possess:

i) the capability of remaining seated (unrestrained) in a standard bus coach seat for the duration of the trip.

ii) the capability of travelling with compact lightweight mobility aids. A standard manual folding wheelchair would be considered a typical transportable mobility aid; however electric wheelchairs and electric scooters (due primarily to their size and weight) would not be considered transportable.

A number of bus terminal related constraints were identified in this study, however the major elements which have emerged from this project are the need for prenotification (reservations), preboarding and a reduction in the level of effort required to complete the transfer. While some potential passengers may object to prenotification and one can sympathize with this in principle, it is clear that the degree of mobility or immobility of a passenger determines both the level of effort (number of staff) and equipment which may be required to board the passenger. Prior notification allows necessary arrangements to be made beforehand thereby avoiding disappointment and delays to the arriving passengers. Constraints such as the presence of queuing gates on platforms will necessitate, in many terminals, the preboarding of passengers. A station based lift device, to be responsive to the need to reduce manpower requirements to transfer passengers, should be designed to be operated by a single person.

Vehicle related constraints were also addressed and the primary finding is that the development of a station based lift device is severely restricted by the currently available area within the bus entrance/stairwell area. Preliminary investigations of a number of potential bus modifications indicate it would be feasible to incorporate minor modifications to the current bus fleet. Minor modifications identified include a removable safety bar/vanity panel, increased door angle opening and improvements to the seat design to provide removable armrests. However, all potential bus modifications would have to be considered in conjunction with the specific needs or requirements of a proposed lift device and be developed for adequate safety, functional and cost effectiveness as an integral component of the overall boarding device.

The serious safety concerns as well as deficiencies identified in the functional and structural aspects of the Kingston Transfer Chair clearly demonstrate the importance of a structured approach to the design of a station based lift device including the development and testing of prototypes or full scale mock-ups in exploring any concept. However, while a number of deficiencies associated with the Kingston Transfer Chair may have been avoided had this process been followed, it is clear considerable work would be necessary to reduce the level of effort which is required to transfer a seated person to the Kingston Transfer Chair.

The primary output of this study has been on the development of design criteria for a station based lift device for intercity bus transportation. Through the application of these design criteria, various station based lift designs may be developed, refined and evaluated. The recommended design criteria and weighting scheme provide a structured approach for choosing the preferable solution among alternatives and provide a basis for optimizing various designs.

The next step in the development of a station based lift device would be the formulation and evaluation of **Conceptual Designs.** It is understood a number of concepts for the station based lift device have recently been developed. These concepts may require further development and/or improvement based on a review of the recommended design criteria. In addition, other concepts may be developed given the availability of design criteria. The recommended design criteria and weighting scheme would then be applied to identify the most promising solution among the alternatives.

The conceptual design and evaluation phase would be followed by **Functional Design, Prototype Development, In-service Demonstration** and **Production Model Development.**

This structured approach to the design process would provide an opportunity for the station based lift device for intercity bus transportation to be developed in a practical, effective and efficient manner.

APPENDIX "A"

SELECTED CSA STANDARDS

7. Wheelchairs (All Vehicles)

7.1 Space Requirements

For the purpose of determining the GAWR and GVWR, the average floor space for each wheelchair shall be taken as 685 × 1115 mm (27 × 44 in). The 1115 mm length shall be parallel to the vehicle's longitudinal centre line.

7.2 Securement

7.2.1

Every wheelchair position shall be provided with a wheelchair securement device that conforms to the strength requirements specified in CMVSS 207. For the purposes of this test, the wheelchair weight shall be taken as 45 kg (100 lb). Where the wheelchair securement device and the occupant restraint device (see Clause 7.3) are combined in a common system, those parts which provide the combined restraining force shall have a combined strength according to the strength requirements specified in CMVSS 207 and 209.

7.2.2

The wheelchair securement device(s) shall be designed to limit the forward and backward rotational, lateral, or vertical motion of all occupied or unoccupied wheelchairs to 10 mm (3/8 in) in any direction at any point of contact with the floor when the vehicle is being operated under the following conditions, using 120 kg (250 lb) as the weight of the wheelchair and occupant:

(a) full throttle acceleration on dry pavement from a standstill to 40 km/h (25 mph) with the vehicle at

(i) its curb weight plus one occupied wheelchair;

(ii) its curb weight plus the design number of occupied chairs;

(b) maximum braking from 35 km/h (22 mph) to a standstill on dry pavement with the vehicle at

(i) its curb weight plus one occupied wheelchair;

(ii) its curb weight plus the design number of occupied chairs;

(c) driving with the outer front wheel around a

(i) 15 m (50 ft) diameter circle at a minimum steady speed of 19 km/h (12 mph);

(ii) 22.5 m (75 ft) diameter circle at a minimum steady speed of 22.5 km/h (14 mph); or

(iii) 30 m (100 ft) diameter circle at a minimum steady speed of 26 km/h (16 mph).

7.3 Wheelchair Occupant Restraint

7.3.1

There shall be an occupant restraint system at every wheelchair position. The restraint system shall consist of at least a lap belt. If a lap and shoulder belt system is provided, it shall not be possible to use only the shoulder belt. The wheelchair securement force shall not be cumulative to the occupant restraint system.

7.3.2

The occupant restraint system components shall comply with the strength requirements of CMVSS 209.

7.3.3

The anchorages for the occupant restraint system shall comply with the strength requirements in CMVSS 210

8. Lifts (All Vehicles)

8.1 Securement to Vehicle

The lift shall be secured to the vehicle so that it can withstand a horizontal force resulting from a 20 g deceleration in any direction.

8.2 Platform Dimensions

Lifts shall have the following minimum dimensions

(a) width—760 mm (30 in); and

(b) length—965 mm (38 in)

Note: *See Appendix A, Clause A8.*

8.3 Capacity

8.3.1

Each lift shall be designed to lift a minimum load of 275 kg (600 lb);

8.3.2

There shall be no evidence of failure when a static load test is conducted, as follows, with the lift attached to a rigid test fixture:

(a) a load of 10 000 N (2 400 lbf) shall be applied through the centroid of a test pallet placed at the centroid of the platform when the platform is positioned at the equivalent to the vehicle floor level. The pallet shall be 600 × 600 mm (24 × 24 in);

(b) the load shall remain on the platform for a minimum of 2 min; and

(c) after the load has been removed, an inspection shall be made to determine if any failures have occurred.

8.4 Platform Construction

8.4.1

The platform shall be skid-resistant.

8.4.2

The sides of the platform shall be fitted with guards which are 25—50 mm (1—2 in) in height and which extend the full length on each side of the platform.

8.4.3

The platform shall be equipped with a lip at the outer edge. This lip shall be approximately in the vertical position when the platform is in the lifting and lowering mode and shall be retracted when the platform reaches the lower limit of travel. The lip shall be a minimum of 100 mm (4 in) in height in the raised position.

8.4.4

Where the lift platform extends outside the vehicle body, the platform shall be equipped with a handrail which is 635 to 865 mm (25 to 34 in) from the platform and shall remain at a constant height while in operation. The handrail shall be capable of withstanding a horizontal force of 450 N (100 lbf) concentrated at any point.

8.4.5

Where the lift platform extends outside the vehicle body, the platform shall be equipped with a restraining device which shall be in position 635 to 865 mm (25 to 34 in) above the platform when the platform is in the operating position to prevent the wheelchair and occupant from rolling off the platform.

8.5 Guarding of Moving Parts

Exposed moving parts, such as chains, sprockets and gears, shall be guarded against hazards inherent in moving machinery.

8.6 Operating Conditions

Lifts shall be capable of functioning in an ambient temperature of −40 to +40°C (−40 to +104°F).

8.7 Rated Speed

The rated speed for lowering and raising the platform shall be a minimum of 0.06 m/s (12 fpm) and a maximum of 0.13 m/s (25 fpm) from a no load to a rated load condition.

8.8 Controls

8.8.1

The control(s) shall be located so as to enable the operator to stand anywhere around the edge of the platform when operating the lift, shall be operable using one hand only, and shall be a continuous pressure operation.

8.8.2

There shall be only one control which shall have a recessed button. Provision shall be made for safe storage of the control device when not being used by the operator.

8.8.3

The controls shall be equipped with a device which is designed to prevent operation of the lift, if the parking brake is not engaged.

8.8.4

The lift shall be equipped with a manual override to enable the operator to raise and lower the platform with or without load in case of power failure, and to enable the operator to return the lift to the stowed position. The override device shall be accessible for use by the operator. A notice in English or French, or English and French, which outlines detailed step-by-step instructions for the hand-moving procedure, shall be posted alongside the hand-moving actuation point.

8.8.5

A powered closing platform shall fold only when it is in the "up" position and shall not fold with more than 22 kg (50 lb) on the centre of the platform.

8.9 Fail-Safe Device

The lifting system shall be so designed that in the event of power failure the average speed of descent of the platform with rated load will be not more than the maximum rated speed (see Clause 8.7).

8.10 *Deleted.*

8.11 Reliability and Durability

8.11.1

There shall be no evidence of failures or creation of hazardous conditions during the accelerated life cycle test in Clause 8.11.2. Electrical components and wiring, hydraulic components, drive components, and fasteners shall be considered as integral parts of the lift system for purposes of the test.

8.11.2

An accelerated life cycle test shall be performed by repeating the lift use cycle 4400 times in an ambient temperature of 10—32°C (50—90°F) as follows:

(a) the time between each cycle shall be between 6 and 7 min;

(b) alternating cycles of loaded and unloaded platform shall be simulated by applying a load of 2670 N (600 lbf) for 100 cycles and then removing the load for 100 cycles. The lift shall be folded and unfolded during each cycle of the unloaded test;

(c) a visual inspection shall be made without disassembly of the lift at intervals of 500 cycles, and changes in alignment, component wear, and loosening of fasteners shall be recorded; and

(d) preventative maintenance shall be performed during the test in accordance with the manufacturer's instructions.

8.12 Cautions

8.12.1

Wording such as the following shall be shown on the lift:

CAUTION—STAND CLEAR.

8.12.2

The lettering specified in Clause 8.12.1 shall be

(a) a minimum of 25 mm (1 in) in height;

(b) in English or French, or English and French;

(c) in a colour that contrasts with the background; and

(d) readily visible.

9. Service Ramps (All Vehicles)

9.1 Gradient

The maximum gradient of the ramp shall be 1 in 4.

9.2 Construction

9.2.1

The surfaces of the ramp shall be made of skid-resistant material and shall be a minimum width of 760 mm (30 in).

9.2.2

The sides of the ramp shall be fitted with guards which are 25 to 50 mm (1 to 2 in) in height.

9.3 Capacity

The ramp shall be designed for a load of 340 kg (750 lb) distributed evenly over a length of 1100 mm (42 in) and the full width of the ramp half-way up the ramp.

9.4 Power Operated Ramps

9.4.1 Guarding of Moving Parts

Exposed moving parts, such as chains, sprockets, and gears, shall be guarded against hazards inherent in moving machinery.

9.4.2 Operating Conditions

Ramps shall be capable of functioning in an ambient temperature of −40 to +40°C (−40 to +104°F).

9.4.3 Controls

9.4.3.1

There shall be only one control which shall have a recessed button. Provision shall be made for storage of the control when not being used by the operator.

9.4.3.2

The controls shall be equipped with a device which is designed to prevent operation of the ramp, if the parking brake is not engaged.

9.4.3.3

The ramp shall be equipped with a manual override to enable the operator to raise and lower the ramp, and to enable the operator to return the ramp to the stowed position in case of power failure. The override device shall be accessible for use by the operator. A notice in English or French, or English and French, which outlines detailed step-by-step instructions for the hand-moving procedure, shall be posted alongside the hand-moving actuation point.

9.5 Securement

If the ramp is stored in the passenger compartment, it shall be secured to the vehicle so that it can withstand a horizontal force resulting from a 20 g deceleration in any direction.

APPENDIX "B"

SAMPLE EVALUATION SCORE SHEET

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(1)	Exterior Appearance			Score	Score
	(a) Obtrusiveness	. Blends into architecture and vehicle environment.		_ x (30) = ____	_ x (30) = ____
	(b) Form	. Integration of colours, surface textures and structural components.		_ x (30) = ____	_ x (30) = ____
	(c) Protrusions	. No sharp corners or overhanging structures.	. Corners or overhanging structures are mitigated.	_ x (40) = ____	_ x (40) = ____
				x (10)	x (10)
				====	====
(2)	Device/Coach Interface			Score	Score
	(a) Compatibility to various coach designs	. Current intercity bus fleet.	. MCI-"MC9", Prevost - "Marathon/Mirage".	_ x (20) = ____	_ x (20) = ____
	(b) Requirements for bus modifications	. None.	. Minor coach modifications limited to coach entrance/stairwell area components.	_ x (20) = ____	_ x (20) = ____
	(c) Level of effort required to deploy the device	. 2 minutes - minimal effort with clear visible reference points for positioning device in the stairwell.	. 3 minutes - medium effort with reference points provided to position device.	_ x (20) = ____	_ x (20) = ____
	(d) Physical link	. Positive link between coach and proposed device.	. High friction connection.	_ x (15) = ____	_ x (15) = ____
	(e) Visual cues for positioning device	. Provide high target value under all lighting and weather conditions.	. Provide clear target under most lighting and weather conditions.	_ x (10) = ____	_ x (10) = ____
	(f) Damage risk to coach during interfacing process	. Provide complete protection to coach doorway and stairwell components during use.	. Minimal risk for limited damage to coach doorway and stairwell components during use.	_ x (15) = ____	_ x (15) = ____
				x (10)	x (10)
				====	====

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(3)	**Passenger Safety/Comfort**			Score	Score
	(a) Passenger protection	. No exposure (of limbs and/or clothing) to moving or rotating parts. Complete body support to avoid contact with coach during ascent/descent. . Provide comfort/safety belt to insure passenger is properly positioned in seat.		_ x (20) = ____	_ x (20) = ____
	(b) Passenger comfort	. All components of the device which physically come in contact with the passenger should be covered or padded and be warm to touch.	. Major components which come in contact with the passenger should be padded.	_ x (10) = ____	_ x (10) = ____
	(c) Level of effort required for transfer	. Minimal (unassisted).	. Medium - 1 person assisting.	_ x (15) = ____	_ x (15) = ____
	(d) Seat comfort	. Padded with medium density foam to avoid "bottoming". . Armrest padding to be firm. . Measure 90 cm across/40 cm deep with a seat backrest angle of 105-110°, a seat angle of 5-10° and an armrest height of 18-20 cm above seat height.	. Padded seat, measure 40 cm across and deep and provide stable armrest.	_ x (10) = ____	_ x (10) = ____
	(e) Armrests	. Armrests should extend beyond the front of the chair to aid those transferring passengers with upper body strength. . Armrests should be stable and individually support 45 kg.		_ x (10) = ____	_ x (10) = ____
	(f) Footrest	. Lower limbs should be supported under the soles, on back of heels and laterally, noting a high proportion of potential users have little control over their lower limbs. . Footrest should support 115 kg passenger and be located as close to the ground as possible during the transfer into the chair.	. Footrest should support 100 kg passenger.	_ x (5) = ____	_ x (5) = ____
	(g) Ascending and decending acceleration	. Gradual acceleration (not to exceed 90 cm/sec^2).		_ x (10) = ____	_ x (10) = ____
	(h) Vibration of passenger seat	. No significant vibration.	. Minimal vibration.	_ x (10) = ____	_ x (10) = ____
	(i) Noise levels during operation	. Comparable to light traffic at 15 m, may be considered intrusive (60dB).	. Comparable to highway traffic at 15 m, telephone difficult to use (70dB).	_ x (10) = ____	_ x (10) = ____
				x (25)	x (25)
				____	____

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(4)	**Functional Adequacy**			Score	Score
	(a) Personnel Requirements to manoeuvre, position and assist the passenger, transfer and seat the passenger.	. Maximum one person.	. Maximum 2 persons.	_ x (15) = ____	_ x (15) = ____
	(b) Preboarding	. Not required.	. Preboarding required but in a designated area.	_ x (10) = ____	_ x (10) = ____
	(c) Ease with which it can be moved about the terminal (operating environment)	. Accommodate 0-2% sloping platform and 0-30 cm curb height and varying concrete/asphalt surface.	. Accommodate varying 0-1% sloping platforms and 0-15 cm curb height and concrete surfaces.	_ x (15) = ____	_ x (15) = ____
	(d) Effort/time required to transport device from storage to the platform area	. A sustained push/pulling/lifting force of less than 130 N for no longer than 2 minutes duration (transport time less than 3 minutes).	. A sustained push/pulling/lifting force of less than 180 N for no longer than 4 minutes duration (transport time less than 8 minutes).	_ x (10) = ____	_ x (10) = ____
	(e) Aids for transporting device	. Adjustable height from 85 to 100 cm providing good grip and friction qualities able to accommodate 95th percentile male hand with gloves.	. Fixed height between 85-100 cm with good grip and able to accommodate 95th percentile male hand with gloves.	_ x (10) = ____	_ x (10) = ____
	(f) Centre of gravity	. Shall be located to minimize the propensity to overturn while sufficiently high to minimize effort required to move the device when force is applied to the handles.	. No overturning potential under normal operation.	_ x (10) = ____	_ x (10) = ____
	(g) Width (while transporting)	. Maximum 90 cm	. Maximum 100 cm	_ x (10) = ____	_ x (10) = ____
	(h) Device positioning	. Positive immobilizing position required for device on platform surface and on coach floor landing, adjustable according to coach type. . If foot controlled, foot remains on floor and applies a maximum force of 3 N.. . When hand controlled, lever may travel through a maximum of 15° angle with a maximum force of 30 N.		_ x (10) = ____	_ x (10) = ____
	(i) Portability	. Stowed in the bus baggage area.	. Limited to remaining at the terminal.	_ x (10) = ____	_ x (10) = ____
				x (15)	x (15)
				═══	═══

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(5)	**Accessibility**			Score	Score
	(a) Seat design	. Seat height adjustable 35-50 cm. . Footrest to seat separation adjustable: 35-50 cm. . Stable chair, footrest and supporting removable armrest. . Minimal physical contact between passenger and operator while adjustments are carried out.	. Seat height (45 cm). . Footrest to seat separation (45 cm). . Stable chair, footrest and supporting removable armrest.	_ x (35) = ____	_ x (35) = ____
	(b) Device size/area remaining for passengers	. 80 x 120 cm is required adjacent to the lift device on the platform to ensure passengers may adequately perform the transfer into the seat.		_ x (30) = ____	_ x (30) = ____
	(c) Transfer time from when the passenger begins to transfer into device chair until the passenger is seated into the coach	. Less than 2 to 3 minutes.	. Less than 5 minutes.	_ x (35) = ____	_ x (35) = ____
				x (15)	x (15)
(6)	**Technical Requirements**			Score	Score
	(a) Power	. Either self contained source or obtained from coach.	. Self contained, obtained from coach or 110 AC from terminal building.	_ x (15) = ____	_ x (15) = ____
	(b) Manual override	. Device should be equipped with an easily accessible manual override system requiring minimum effort by the operator. (Two minute execution time.)	. Device should be equipped with an easily accessible manual override system requiring minimum effort by the operator. (Five minute execution time.)	_ x (15) = ____	_ x (15) = ____
	(c) Lift/chair speed	. Infinitely variable from 0 to 7.8 metres per minute.	. Variable, 1.2 meters per minute increments, maximum 7.8 metres per minute.		
	(d) Selection of components	. Exclusive use of standard off the shelf components/hardware.	. Maximum use of standard off the shelf component/hardware.	_ x (10) = ____	_ x (10) = ____
	(e) Pay load	. 115 kg	. 100 kg	_ x (10) = ____	_ x (10) = ____
	(f) Design load	. 575 kg, i.e., safety factor of 5.	. 400 kg, i.e., safety factor of 4.	_ x (10) = ____	_ x (10) = ____
	(g) Design life	. 1500 cycles minimum (5 years in service)	. 1000 cycles minimum (3 years in service)	_ x (10) = ____	_ x (10) = ____
	(h) Maintenance/Servicing	. Not required throughout design life.	. Service required twice a year. . Good access to all serviceable components.	_ x (20) = ____	_ x (20) = ____
				x (20)	x (20)

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(7)	Control System			Score	Score
	(a) Control system features	. Failsafe device - in the event of power failure, average descent speed less than 7.8 metres/minute. . Equipped with a device to prohibit operation when not properly immobilized and/or engaged. . Automatic reset control to reset all controls to the off position (when power is interrupted). . Automatic deceleration near the termination of up and down chair position.		_ x (30) = ____	_ x (30) = ____
	(b) Function of control panel	. Movements of the seat/chair up/down with speed adjustment. . Stopping of seat/chair gradually. . Indicate operation status "on" or "off". . All controls to provide audio feedback (i.e., click).	. Adjustable speed on the control panel.	_ x (30) = ____	_ x (30) = ____
	(c) Location of controls	. If remote controlled it should be shock resistant material and sustain no damage or switch activation from a 1.5 m fall onto concrete surface. . Remote control unit should fit in one hand and be activated with same hand (either right or left) with or without gloves. . Fixed control panel should be located to ensure operator has unobstructed view of the entire operation and be mounted 100-110 cm at an angle of 0-15°.		_ x (10) = ____	_ x (10) = ____
	(d) Information portrayed on controls	. Both official languages, using symbols and colours to clarify and highlight functions, with up control on the upper part of the panel and down on the lower part. . Provide illumination at night.		_ x (20) = ____	_ x (20) = ____
	(e) Switch type	. Push buttons - 2.5 sq.cm area with maximum 32 mm fully depressed using a force of 1 to 8 N. . Barrier (lip) to prevent accidental activation of push buttons.		_ x (10) = ____ x (10) ____	_ x (10) = ____ x (10) ____
			TOTAL ALL DESIGN CRITERIA (SUM OF SUB-TOTALS)	____	____

APPENDIX "C"

TRANSFER CHAIR TEST FINDINGS
AND IMPLICATIONS ON THE DEMONSTRATION PROJECT

TRANSFER CHAIR TEST FINDINGS

AND IMPLICATIONS

ON THE

DEMONSTRATION PROJECT

MARCH 1986

DeLCan (De Leuw Cather, Canada Ltd.)
in association with
TES Limited
Rutenburg Design

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1.0 INTRODUCTION

There currently exists a trend towards increased travel by persons with mobility restrictions. As this market increases, the transportation industry is recognizing the need to develop devices which overcome barriers inherent in the transportation system. One such barrier - stairs leading onto intercity buses can create difficulties for many segments of the elderly and disabled population. For this reason, the "Kingston Transfer Chair" has been developed. This device, which is intended to enhance intercity travel, moves passengers with mobility restrictions up or down the stairwell of intercity buses. Potential benefits initially cited during development of the device were reduced risks taken by bus terminal employees by eliminating the need to carry non-ambulatory passengers into/out of buses, increased ridership for intercity bus travel and the elimination of bus modifications resulting from retrofits such as wheelchair lifts to make the vehicles accessible for the mobility impaired.

The Kingston Transfer Chair is a relatively simple device which is positioned into the doorway of the bus to a position where the upper end of the boom is near the bus driver's seat (see Figure 1 and Photograph 1). A disabled person may then be positioned into the chair and raised by means of an electrically driven feedscrew into the bus through the conventional doorway opening.

The major objective of this project therefore, is to test and evaluate the suitability of the Kingston Transfer Chair system as a boarding/deboarding device for the elderly and disabled with respect to intercity bus transportation.

The Terms of Reference for this project placed considerable emphasis on the conduct of an "in service" demonstration project. In short, the evaluation and testing, to a lesser extent, would be gained through the experience of operating a number of the transfer chair devices within the Quebec-Windsor corridor. Prior to the devices being put into service, they were to be

PHOTOGRAPH 1

Prototype Transfer Chair

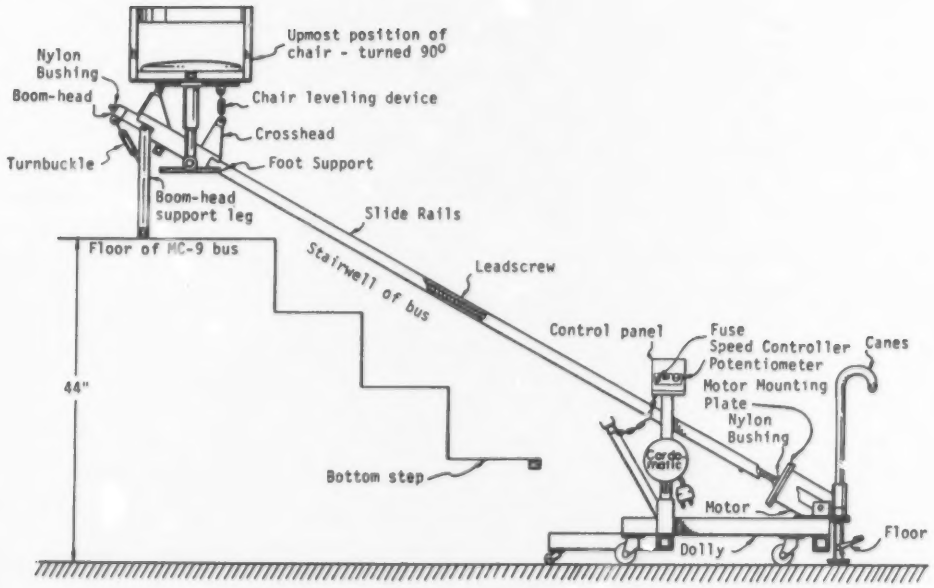


FIGURE 1

subjected to some preliminary tests, referred to herein as the "predemonstration phase" of the project. Following the demonstration period of the device, a review of the performance of the device was to be undertaken and minor modifications or enhancements suggested as part of the "post-demonstration phase". Each of these project phases are described briefly in the following paragraphs.

The predemonstration phase was identified as a three-month preparation period prior to the commencement of the "in-service" demonstration project. The primary activities carried out in this phase were to be the mechanical testing, ergonomic testing and preparation of user surveys, publicity and other associated material required for the successful conduct of the demonstration project. The role of the mechanical testing and the ergonomic evaluation was to ensure that the proposed transfer chair met basic functional, structural and safety considerations.

The demonstration phase of the study was to occur over a 12-month period with transfer chairs being made available in five bus terminals: Quebec City, Montreal, Ottawa, Toronto and London. During this phase of the study, it was intended to monitor the usage of the transfer chair, to coordinate data collection in the form of questionnaires and to provide assistance to the terminal operators with regard to mechanical breakdown and/or device failures.

It was suggested that the post-demonstration phase review the survey findings, focusing on the acceptability of the transfer chair, its strengths and its weaknesses, identify enhancements, estimate production costs and identify the market potential and applicability to other modes.

This report documents the study findings as they pertain to Phase A - the Predemonstration Phase. More specifically, the focus is directed towards the results of the mechanical testing and the ergonomic evaluation both of which have significant implications with regard to Phase B - the Demonstration Project.

2.0 ERGONOMIC EVALUATION AND MECHANICAL TEST FINDINGS

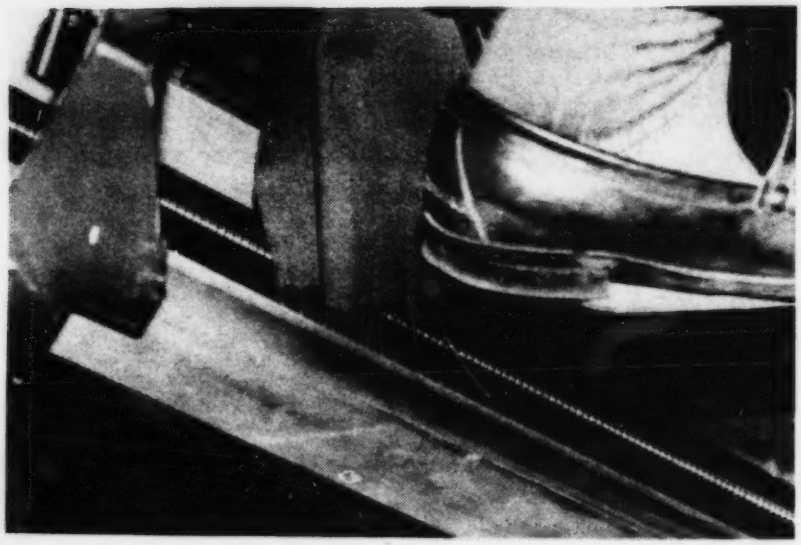
Two of the five transfer chairs were made available to the study team, one of which was subjected to the physical mechanical testing and the other underwent the ergonomic evaluation. A detailed account of the mechanical test program and the ergonomic evaluation is contained in Appendix A and Appendix B respectively.

An overview of the test findings, as they relate to safety, structural integrity and functional adequacy, is presented in the following pages.

2.1 Safety

Several observations during the mechanical and ergonomic evaluations indicate the transfer chair has some serious shortcomings in this area. A major deficiency identified in this regard was the exposed feedscrew. The feedscrew rotates at a high rate of speed and is centred below the seating position of the user. The close proximity between the user and the open feedscrew creates an undesirable situation whereby pieces of clothing worn by the user or unprotected lower limbs of the user could become entangled in the mechanism. Photograph 2 clearly indicates this potential hazard.

The transfer chair is controlled via a control panel consisting of an on/off switch, a forward/brake/reverse switch and a variable speed control (rate of ascent or descent). A number of deficiencies were noted with regard to the control panel. Most significant among those was the lack of an automatic reset switch. For example, when the power supply is interrupted, the on/off switch does not return to the off position and consequently, when power returns, the device is immediately reactivated. This arrangement can result in a situation where the operator may not be stationed near the control panel when power is regained thereby resulting in unattended operation of the



PHOTOGRAPH 2

Feedscrew is exposed full length of boom. Clothing and unprotected limbs of user are vulnerable to rotating screw.

device which is clearly undesirable from a safety point of view. In addition, the fact that the instructions on the control panel (i.e., "forward" and "reverse" rather than "up" and "down") are unclear, increase the opportunity for error on the part of the inexperienced operator. The operation of the device is, therefore, very much dependent on the ability and previous experience of the operator which is clearly not an ideal situation.

The adjustment and securement method of the seat assembly was considered to be another safety feature of some concern. The levelling of the chair to provide for seating comfort requires considerable effort and is dependent on the ultimate boom angle as the upper end of the boom is placed into the bus. Adjustments were found to be onerous and the type of fasteners were considered substandard as they did not prevent the chair, under certain conditions, from tilting backwards. This situation could be hazardous in the event that a user were to brush against the door or come in contact with the coach entrance upon descent. Also, the chair's rotating feature allows the chair to be turned at either end of the boom to facilitate access to and egress from the chair in loading/unloading. This feature compromises its ability to provide a safe, secure ride since no locking mechanism is provided to ensure that the chair does not swivel freely during its ascent or descent, thereby introducing, for example, an opportunity for the user's knees to come into contact with the control panel post.

2.2 Structural Integrity

The evaluation of the structural integrity of the transfer chair was carried out through the application of several test procedures. These test procedures were developed to simulate actual field conditions. The test program included cycling the device 1000 times (assumed to represent approximately three years of usage) with its design load of 135 kg (300 lbs). This section of the report outlines the results of the cyclic testing of the floor locks and of the transfer chair device, as well as the overall structural degradation which resulted during testing.

2.2.1 Floor Lock Cycling

The cyclic testing of the floor locks was identified as an important element in the evaluation of the transfer chair's acceptability primarily because they are responsible for immobilizing the transfer chair while the passenger is boarding and/or deboarding. Any failures related to the floor locks' ability to secure the transfer chair would jeopardize the safe, efficient movement of passengers into and out of the bus.

The floor locks were subjected to approximately 1000 cycles during which the spring stiffness decreased progressively over the cycle program but remained fully operational. In addition, skid resistance tests were performed on a smooth painted concrete floor and a rough concrete surface. Each surface was evaluated under varying conditions of dry, wet and sand covered as would be encountered in the "in service" demonstration program. The measured coefficients of friction during these tests varied from 0.67 for rough concrete (both wet and dry) to 0.27 for smooth painted concrete covered with sand. These results suggest the floor locks would behave adequately (under all cases except sandy surfaces), a condition which is not expected however, to be prevalent under normal operating conditions.

2.2.2 Transfer Chair Cycling

The transfer chair was subjected to 1000 cycles of use. This offered an excellent opportunity to record its performance and monitor operational degradation. The operation of each cycle was carried out in accordance with instructions found in the operator's manual. Some of the most significant results are summarized below.

In general, the transfer chair required a considerable amount of attention throughout the 1000 cycles: the frequent tightening of bolts and fasteners, and repeated application of a lubricant to the slider, clearly indicated inappropriate choice of hardware and selection of materials. The care and

attention given the transfer device during the testing was considered to be far above the level which could be expected from the terminal operators during normal operation.

Vibration levels were recorded and, while initial vibration readings were significant but not excessive at the start of the test program, the average vibration levels continued to increase progressively during the cycling. Some of the contributing factors to this increase may be related to the bent feedscrew; the significant wearing of the nylon runners; the narrowing of the spacing of the slide rails which had the effect of introducing significant side to side play causing the chair to twist and turn slightly as it travelled up and down the boom and the general looseness which the drive mechanism exhibited. Typical feedscrew vibration during the latter stages of testing is illustrated in Photograph 3. As shown, the feedscrew centred between the two slides experienced vibrations with a maximum amplitude of approximately 10 cm (4 in). These vibration levels were significant enough to cause a substantial slowing of the chair near the middle of descent and to project a very negative image with respect to the safe operation of the device.

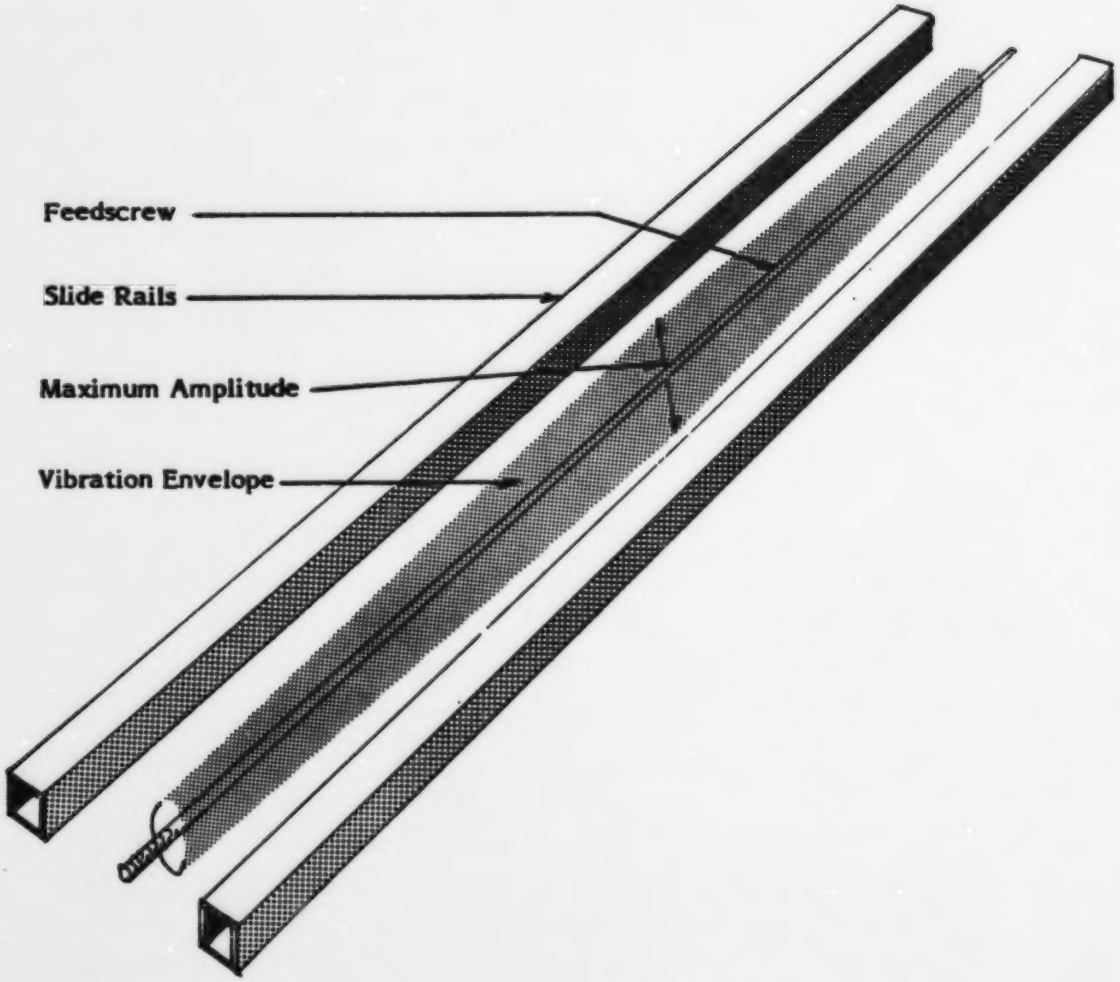
2.2.3 Structural Degradation

A number of critical components experienced deformation, including crack propogation during testing. The feedscrew, due to the torque applied and, to a lesser extent, the vibrations experienced, resulted in a slightly bent feedscrew.

The slide rails as previously mentioned, experienced slight deformation resulting in the outside spacing of 30.5 cm (12 in) being reduced to 29 cm (11.5 in). This difference of 1.5 cm (0.5 in) provided considerable room for side-to-side movement of the transfer chair and the sliders, thereby conveying a very unstable feeling to the potential user of the transfer chair.

PHOTOGRAPH 3
(Graphic Illustration)

Typical Feedscrew Vibration (10 cm Amplitude)



Weld cracking was observed in a number of areas on the transfer chair device and, in some locations, assemblies were no longer effectively joined. For example, cracks in the boom head support leg, progressively became elongated due to an increased load on the cross-member causing an approximate .75 cm (0.25 in) deformation to the support leg.

The resulting structural deformation and weld cracking experienced during the dynamic evaluation program demonstrates the inability of the device to satisfactorily achieve its design objective with its rated design load.

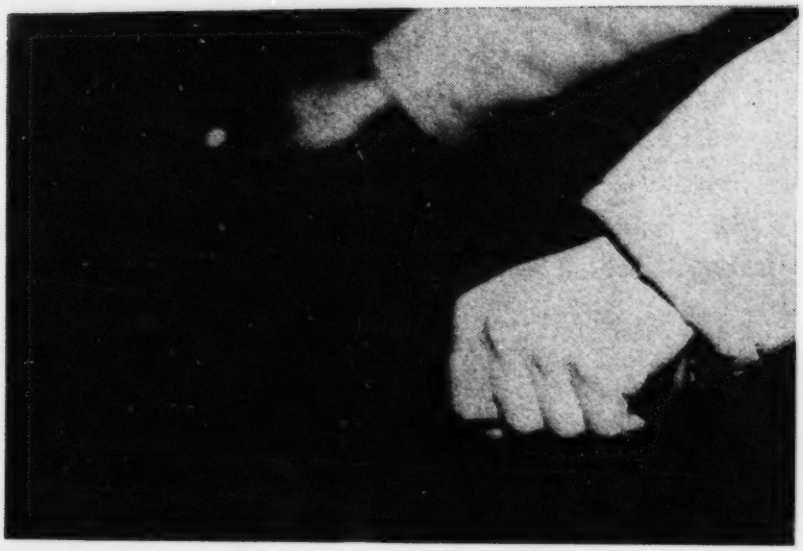
2.3 Functional Adequacy

An important element in the evaluation of any device is "how well does it meet the needs of the operator and/or user?" This section briefly reports on the predemonstration phase evaluation of the Kingston Transfer Chair with respect to both the potential user and the operator.

The Kingston transfer chair is a specialized piece of equipment and has been designed primarily to operate in a very limited environment which offers little operational flexibility. For example, differences between individual terminals such as platform heights and surface conditions will greatly affect the performance of the device. In addition, the movement of the transfer chair between its storage area and the location where it is to be operated has the potential of being a very cumbersome and possibly dangerous operation for the following reasons:

- the device has no clear location from which the device may be manoeuvred or directed and, when an attempt to use the canes is made for this purpose, the fact that they are free to swivel makes this task very onerous (see Photograph 4);
- the casters provide insufficient clearance between the device and the ground and, consequently, the varying floor surfaces and elevation differences limit the degree of ease with which the device may be moved;

PHOTOGRAPH 4



Canes are not fixed, they rotate when force is applied and lift out.

- the device does not pass through a 91.5 cm (36 in) doorway which restricts the operating environment in which it can operate;

- the transfer chair configuration (a long boom projecting outward at the approximate height of a standing or walking person with no warning markings) makes it a potentially hazardous piece of equipment to be wheeling about among other terminal users.

The study team carried out an extensive evaluation of the ease (or lack of) with which potential users, with varying degrees of mobility restrictions, may gain access to this device. It became obvious throughout this evaluation that a great number of basic requirements of the user and operator were not adequately considered in the design of the Kingston Transfer Chair. Some of the findings which relate to the user include the following:

- The chair is relatively inaccessible as barriers exist on all sides (control panel to the left, canes and footrest in the front and the bus door prohibits access from the right). These obstructions restrict the conventional means of transferring persons between chairs.

- The canes are the only visible means of support; however, as physical force is applied, these canes may rotate.

- The seat height is approximately 57 cm (22.5 in) from the ground, an increase of approximately 7.5-10 cm (3-4 in) above the standard wheelchair. This factor requires significant additional effort when transferring a user from a wheelchair. Also, this seat height when approached from a standing position (i.e., elderly users) requires a step to aid the user; however, the foot rest is the only visible means of obtaining this height advantage but, has not been designed to support the weight of the user.

Also of significant concern to the study team was the level of effort required to correctly install the upper boom in the bus. This procedure appears to be an iterative one as no visual references for proper and safe positioning of the transfer chair boom exist. The ultimate positioning of the device is greatly affected by the narrow, restrictive door opening and is severely limited by the fact that the device is significantly constrained when used on buses other than MC9 coaches (i.e., GMC or Prevost). Any deviation from an acceptable positioning could result in a dangerous situation for the potential user given that the chair is free to swivel and may, if the user brushes up against obstructions in the door opening, tilt backwards.

3.0 IMPLICATIONS ON THE DEMONSTRATION PROJECT

The mechanical and ergonomic testing of the Kingston Transfer Chair clearly illustrates that while the concept of a transfer device appears valid, the current transfer chair device has not performed sufficiently well to be tested by the general public. Serious safety concerns as well as functional and structural aspects must be addressed prior to the introduction of this device via a demonstration project.

While the concept of evaluating the transfer chair device within an in-service environment is a desirable one, it is the opinion of the study team that such an approach using the existing Kingston Transfer Chair would compromise the safety of the potential users of the device and would, because of mechanical and functional shortcomings, severely limit its use by bus operators.

It is unfortunate that the Kingston Transfer Chair was unable to meet basic safety, functional and structural requirements since the study team feels the concept of a transfer chair device does offer potential to serve a certain segment of the mobility restricted traveller market. Consequently, further development of the transfer chair concept is required to ensure that all aspects such as user and operator requirements, vehicle constraints and operating environment constraints are considered.

The development of the transfer chair concept into a fully operational device requires a logical, stepwise approach in which various refinements can be incorporated into the designs as the development proceeds. Such a process could include five major tasks, namely: a feasibility study, the functional design, the prototype development, the in-service demonstration and the production model development.

With respect to the feasibility study, which would be the first task to be initiated, the following activities should be undertaken:

- the definition of target user groups;
- the identification of vehicle and operating environment constraints;
- the identification of user and operator requirements;
- the development of concepts for the device;
- the identification of the potential market for the device.

Assuming a positive recommendation to proceed from the feasibility study, functional designs would then be developed with refinements introduced at each step of the process, resulting in a prototype device which can be tested under controlled laboratory conditions, further refined and then put into service via a demonstration project. From results of the demonstration project, the device would then be further refined, thereby, providing the basis for the production models.

APPENDIX "D"

MECHANICAL TEST FINDINGS

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EVALUATION PROGRAM

1 General Outline

One of the five transfer chairs constructed for TDC was evaluated by T E S Limited to assess the general operational and performance characteristics of a typical device. Shown in Photograh 1, the transfer chair was weighed, inspected for assembly integrity and performance tested to determine possible problem areas. A test program was conducted to evaluate the stability, dynamics and operational principles during cyclic operation of the transfer chair.

2 Technical Inspection and Verification

The drive mechanism, slide mechanism, electrical controls and structural assembly were examined for overall workmanship and assembly integrity. The inspection showed that most nut-and-bolt assemblies were loose and required tightening to prevent fastened assemblies from separating during future operation of the device. It was noted that several fasteners would not maintain their securement and should be substituted with alternates that are designed for the intended application. For example, the fasteners that attach the boom to the dolly should provide the necessary securement and permit boom attitude adjustibility without loosening.

Shop drawings 2 through 12, contained in Appendix "A" and supplied as the construction drawings for the transfer chair, were reviewed to verify their technical representation of the prototype device depicted in Figure 1. An inspection of the assembly details showed that all drawings require revisions. Many dimensional inaccuracies result from a boom design change, whereby the slide rail spacing is 2 inches greater than the specified 10 inch

PHOTOGRAPH 1

Prototype Transfer Chair

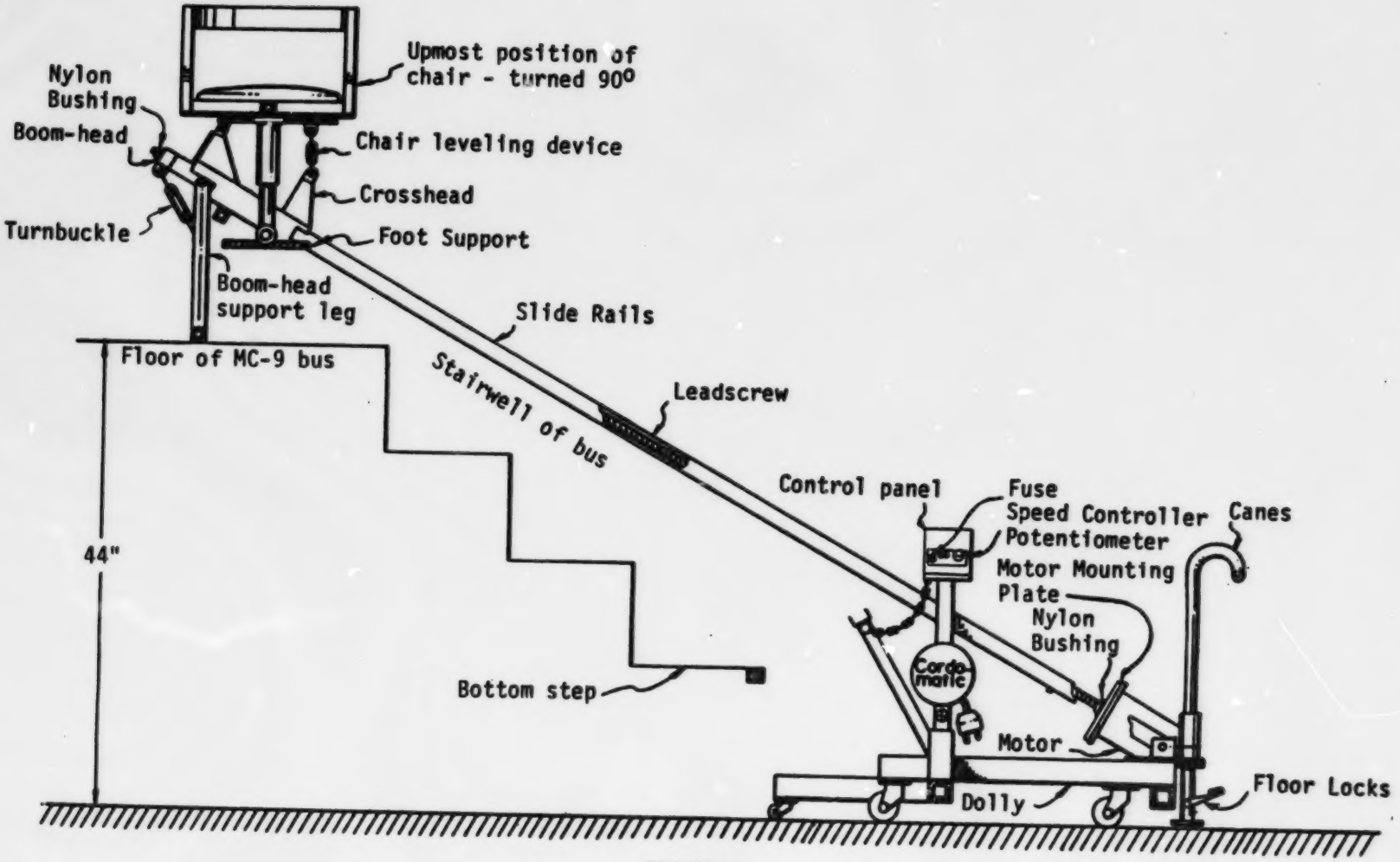


FIGURE 1

Transfer Chair Schematic

dimension. Other noted changes which affect the accuracy of the technical presentation are as follows:

1) The use of a different motor than specified.

2) Redesigned limit switch contact springs.

3) Redesign of the front chair support on the crosshead.

4) Redesign of the boom head support leg.

5) Redesign of the foot rest.

After inspection, the transfer chair weight and maximum load capacity at mid position on the boom were determined. Design calculations showed that the 163 lb. device is capable of supporting a 300 lb. static payload with a safety factor of approximately 4.

3 Dynamic Evaluation

To become familiar with the operating procedure of the transfer chair, several cycles were conducted to review its operation. During the familiarization period, the lock nut on the top of the leadscrew backed off thereby causing the leadscrew to interfere with, and score, the lower nylon bushing. This interference increased the resistance of the drive mechanism and the electrical load on the controller above the 5.1 ampere current rating. Also, the lower bushing assembly, which had once been a press fit in the aluminum housing, had become loose. At this point, it was evident that the leadscrew would require securement in its proper position. Otherwise, general use of the device would require continuous fuse replacement.

Prior to commencing the cyclic test program, the leadscrew was repositioned and the upper bearing assembly was fixed by adding a

second locknut to the top end of the leadscrew. To prevent the lower nylon bushing from travelling up the leadscrew, the assembly was fixed by clamping its retaining ring to the crossbrace. The slide rails were cleaned and lubricated and the device was thoroughly inspected.

The durability and performance of the device was evaluated by conducting a test program whereby the transfer chair was raised and lowered with its rated load for 1000 cycles. Operation of the transfer chair was conducted according to the prescribed procedure in the instruction manual.

At 25 cycles and multiples of 100 cycles, the device was inspected for loose or worn components, structural deformation and cracks. These observations are presented in Table 1. The functional integrity was evaluated at each inspection by recording the following parameters:

1) The torque required to manually raise the chair (at 5 positions along the boom).

2) The time required for the chair to travel a measured section at the centre of the boom in both directions.

3) The wear of the nylon runners.

4) The starting torque to raise the chair (a function of speed control dial position from 0 to 100)

The recorded results are summarized in Table 2.

Throughout the cycle testing, the torque required to raise the chair and the maximum ascent rate remained relatively constant at approximately 10.5 in-lb and 9 in/sec, respectively. However, the descent rate fluctuated from 8.71 to 12.76 in/sec and was a maximum between 200 and 300 cycles. Component deformation and

INSPECTION CYCLE	OBSERVATIONS
0	- all fasteners were tightened - the slide rails, screw and nylon bushings were cleaned and lubricated
25	- no apparent change in the assembly integrity - grease build-up was noticed on the slide rails and the leadscrew
100	- both nuts on the back of the swivel plate were loose - the turnbuckle was loose - the set screw on the speed control knob was loose
150	- the chair no longer remained stationary without application of the brake - the speed control was rendered useless when descending the chair
200	- both nuts on the back of the swivel plate were loose
300	- the slide rail outside spacing had decreased from 12 to 11 3/4 inches at the centre of the boom
300+	- the turnbuckle had to be tightened every 10 cycles - the lock nut under the seat was loose
350	- a horizontal crack was noticed on each side of the rear of the crosshead - a crack was noticed in each side of the boom head support leg - cracks were seen in the motor mounting plate
400	- the bolt had fallen off the turnbuckle upper support - increased vibration - the cracks had propagated - the slide rail spacing had narrowed to 11 5/8 inches at the centre of the boom
400-500	- severe vibration - the low speed vibration amplitude in the leadscrew had become excessive - the chair slowed noticeably when passing through the criticals during descent - the turnbuckle had to be retightened every 3 cycles - the leadscrew top bushing started to push through the crosspiece, causing the aluminum material to crack
600	- the leadscrew had pushed further through the crosspiece - the cracks at the back of the crosshead had propagated through to the inside weld - the crack length on the upper support had increased - the brake was again required to prevent the chair from continuing descent - the slide rail spacing had narrowed to 11 1/2 inches at the centre of the boom
700	- no apparent change in the assembly integrity
800	- the chair slowed substantially due to vibration near the centre during descent - the nut on the speed control potentiometer was loose
900	- the nut on the boom pivot was loose
1000	- the lock nut under the seat was loose

TABLE 1
Dynamic Evaluation Inspection Observations

INSPECTION (CYCLE NUMBER)	MANUAL TORQUE (in - lb)	TRAVEL SPEED (in/sec)		STARTING CURRENT (DIAL POSITION)	NYLON RUNNER WEAR (in x 10^{-3})
		ASCENT	DESCENT		
0	8.8	8.63	8.71	22	0
25	7.8	8.93	8.91	19	1
100	10.4	8.97	9.11	22	3
200	9.4	8.81	12.75	24	6
300	8.8	9.06	12.76	22	10
400	11.4	8.91	8.75	24	13
500	11.2	8.84	8.98	24	15
600	12.0	8.91	12.58	24	18
700	10.2	9.10	9.78	22	19
800	10.0	8.72	8.87	24	21
900	10.4	8.80	8.71	24	22
1000	10.8	8.97	8.99	24	24

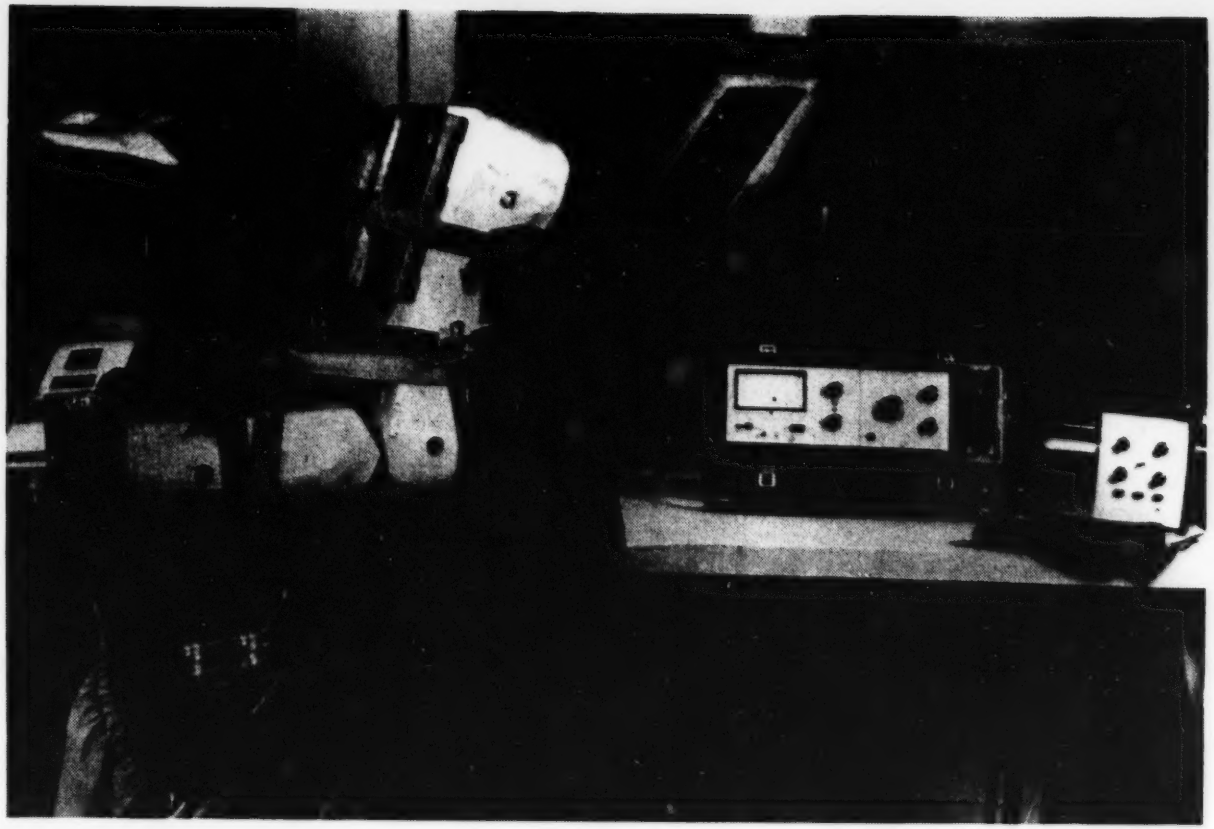
TABLE 2
Dynamic Evaluation Inspection Results

excessive clearance between the slide rails and the nylon runners produced vibrational amplitudes which subsequently caused the descent rate to decrease with increasing cycles (an exception is noted at 600 cycles). This decrease was mainly due to shaft whirling of the leadscrew.

After 150 cycles, the SCR motor speed controller was incapable of controlling the descent rate of the chair and it could only be stopped by setting the switch to the "brake" position. Periodic inspections showed that many fasteners would vibrate loose and the slide rails would accumulate a build-up of a black greasy substance (a mixture of lubricating oil and worn nylon). The nylon runners were observed to have worn .024 inches after having travelled 1000 cycles on the lubricated guide rails.

To monitor the performance degradation of the transfer chair over the cyclic test program, an accelerometer was mounted to the chair support base to observe vibration levels while operating the device. The instrumentation setup is depicted in Photograph 2. Vibration readings were recorded at the first, 150th and 600th cycles. These results are summarized in Table 3.

The recordings indicate that the vibration level was significant at the start of the test program. The high acceleration levels appear to be the result of excitations caused by shaft whirl (due to a slightly bent leadscrew and resonance at the critical shaft lengths). Since it became evident that the "Y" plane experienced the highest levels of acceleration, these readings were used for comparative purposes. Sample traces are presented in Figure 2. As the clearances between the slide runners and the rails increased, the oscillations were observed to have increased. This observation was supported by the manner in which the device moved about, while in operation. The traces recorded at the 600th cycle inspection indicate that the average acceleration level decreased, however, the peak accelerations were significantly higher. The peak acceleration of 39 g occurred at a critical shaft length



PHOTOGRAPH 2

Dynamic Evaluation - Vibration Measurement Instrumentation

CYCLE NUMBER	TRANSFER DIRECTION	ACCELERATION (g)					
		X		Y		Z	
		Avg.	Max.	Avg.	Max.	Avg.	Max.
1	Up	10	21	15	23	8	17
	Down	9.5	21	16	25	9	17
150	Up	-	-	11	25	12	30
	Down	-	-	19.5	25	18	42
600	Up	-	-	9	26	12	36
	Down	-	-	11	39	16	33

TABLE 3

Vibration Readings

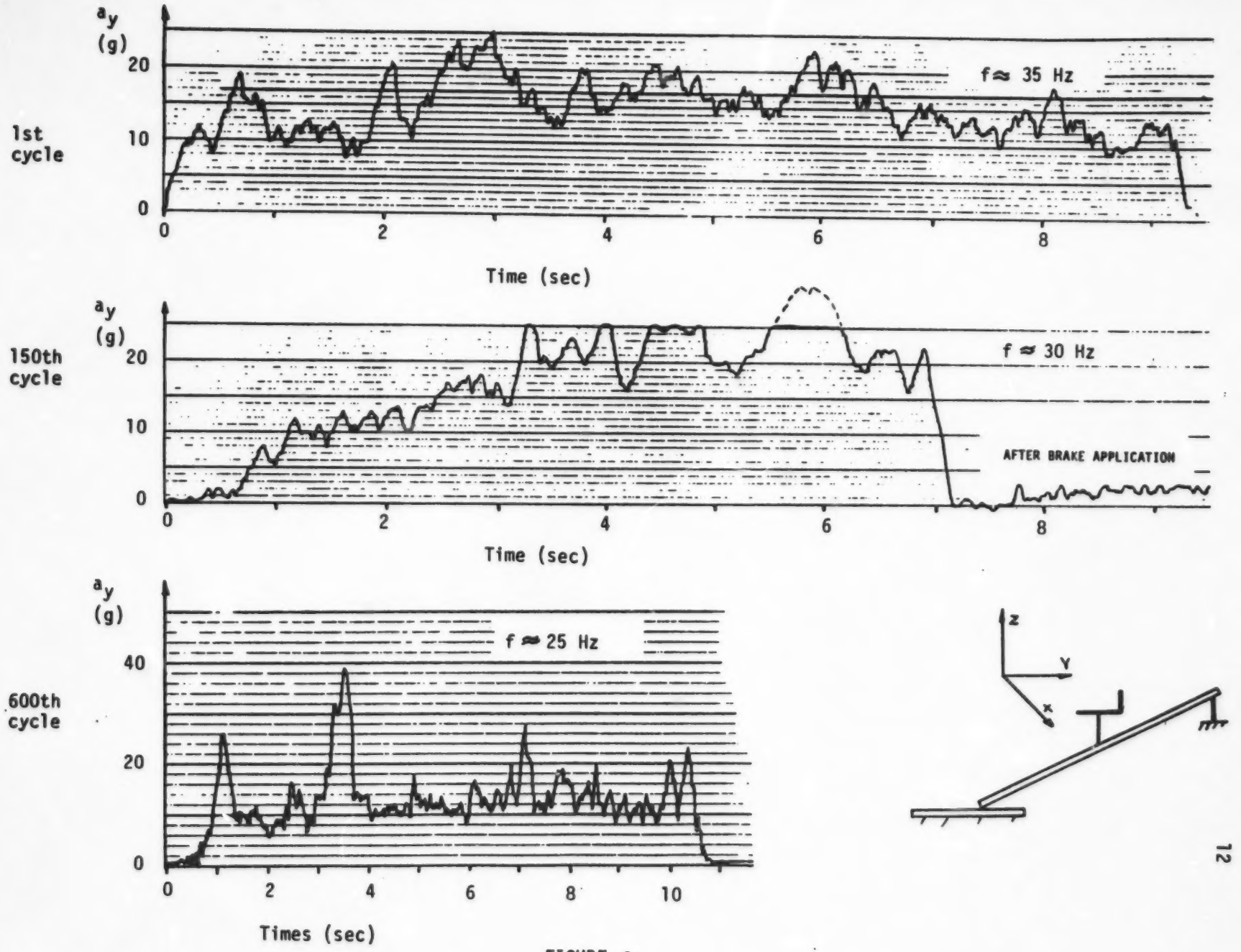


FIGURE 2

Vibration Signatures During Typical Operation

where the leadscrew oscillations had a measured amplitude of 4 in. This leadscrew vibration oscillation is presented in Photograph 3.

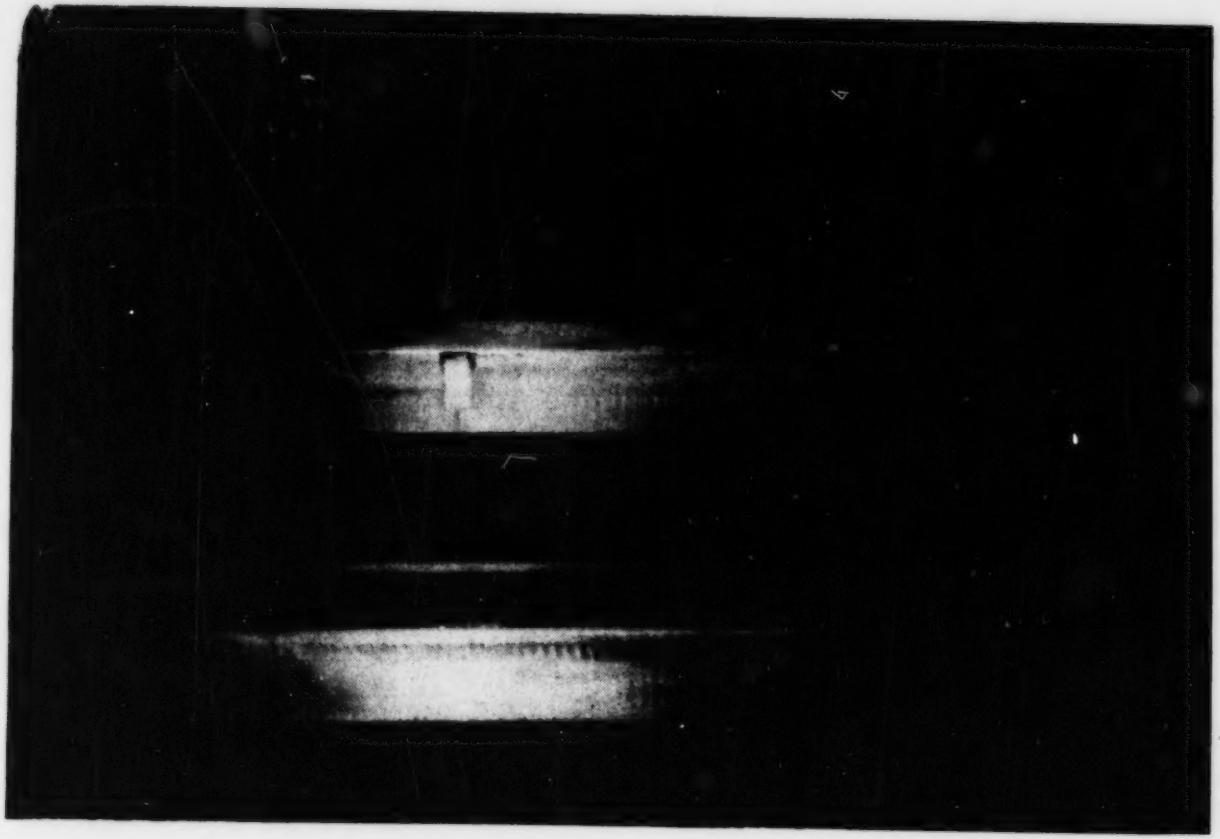
The following findings have been presented to indicate the significance of the problems that were encountered during the cyclic test program:

1) At 150 cycles, the chair would no longer remain stationary without application of the brake. As a result, the speed control was rendered useless as a control to vary the descent rate of the chair. The brake had to be applied to prevent the chair from striking the boom stop at the end of its descent. The brake was activated by moving the directional switch on the control panel to the "BRAKE" position.

2) At 300 cycles, the outside spacing of the slide rails had narrowed at the center length from 12 inches to 11 3/4 inches, and then to 11 1/2 inches at 600 cycles. This resulted in approximately 1/2 inch of side-to-side play in the crosshead and caused the chair to twist and turn slightly as it traveled up and down the boom.

3) At 350 cycles, cracks were observed in 3 welded locations. A horizontal crack was noted in each side of the rear crosshead support. Cracks were also noted in each side of the boom head support leg and in the motor mounting plate. Crack propagation was noted to have increased between 350 and 600 cycles at which point some assemblies were no longer completely joined. As the cracks elongated in the boom head support leg, the increased load on the cross member resulted in an approximate 1/4 inch deformation.

4) At 500 cycles, the leadscrew started to push through the crosspiece at the top end of the boom causing the aluminum material around the nylon bushing to crack.



PHOTOGRAPH 3

Typical Lead Screw Vibration (4 in. Amplitude)

4 Operational Evaluation

The ability of the transfer chair to load or disembark a user was assessed for three intercity bus models at Voyageur Colonial's garage facilities. The device was positioned in the stairwell of a GMC, Prevost and MC9 coach. For each coach, the device was operated to transfer a large (6 ft 1 in, 230 lb) male adult from ground level to the landing area at the top of the coach steps. In transporting the transfer chair to the garage and after performing several transfer operations, the following observations were noted:

1) It is very difficult to move the device over asphalt or dirt covered surfaces.

2) The device will not pass through a 36 inch doorway.

3) It is difficult to position the device in the ideal location in a bus stairwell.

4) The chair angle adjustment and securement is inadequate and unsafe.

5) The electrical cord is too short.

6) The chair, support bracket and foot support adjustments resulting from a required change in boom attitude is time consuming and awkward. (e.g. when changing from an MC9 to a Prevost coach)

7) The transfer chair will not turn sufficiently in the landing area of a GMC or Prevost intercity coach.

8) Entrance and landing clearances require careful boom location and cautionary chair ascent and descent.

9) The exposed lead screw poses a potential safety hazard.

5 Floor Lock Cycle Tests

The transfer chair utilizes two floor locks to hold its position while being operated or stored. Activating the floor locks lowers large non-skid brake pads which support the dolly and maintain its position.

Cycle tests were conducted on the floor locks to monitor functionality and determine whether degradation would occur over 1000 cycles. Prior to cycling, the floor locks were inspected for smoothness of operation, general play, wear and tear and spring stiffness.

The right floor lock was activated and released 1000 times and was inspected for possible defects at 100 and multiples of 200 cycles. The periodic inspections showed that the spring stiffness decreased slightly and after 1000 cycles, the floor lock was noted to engage easier.

A similar test was conducted on the left floor lock while situated over the corner of a 1/4 inch thick plate (to simulate uneven ground). As was the case with the right floor lock, its spring stiffness decreased over the cycle program. At 600 cycles, this lock had a noticeable increase in play.

Inspection of the floor locks after the cyclic testing showed that both were in reasonably good condition and maintained their functionality.

During the dynamic evaluation of the floor locks, several fasteners on the dolly and chair assemblies became loose and required occasional retightening.

6 Skid Resistance Tests

The ability of the device to maintain its locked position on the ground surface, while in operation, was assessed by conducting skid resistance tests. The objective was to ascertain whether the device would lurch forward when the chair (with its rated load) was brought to an abrupt halt during descent. This condition could occur if the chair were to interfere with the door opening or forcefully contact the stops while transferring a user.

The transfer chair was arranged to simulate a typical passenger loading configuration in an MC9 intercity coach. A series of pull tests were conducted on a smooth painted concrete floor and a rough concrete surface, representative of a typical sidewalk. Each surface was evaluated under dry, wet and sand covered conditions. For the six different ground conditions, skid resistance tests were conducted by horizontally pulling the dolly away from the simulated bus floor. Photograph 4 depicts the skid resistance test setup on a rough concrete surface. All tests were conducted with a 300 lb. load in the chair. The forces required to move the unit were recorded with the chair in the downmost, mid and upmost position on the boom. The skid resistance test results are listed in Table 4. The coefficient of friction was calculated for the floor lock brake pad/concrete interface with the chair in the downmost position.

The test results indicated that the floor locks would hold the dolly in position, when the transfer chair was allowed to descend at its maximum rate and strike the bottom stops, in all cases except on the sandy surfaces.

PHOTOGRAPH 4

Skid Resistance Test Setup

SURFACE	CONDITION	SKID FORCE (lb)			COEFFICIENT OF FRICTION
		Chair, Downmost Position	Chair, Mid Position	Chair, Upmost Position	
ROUGH GRAVEL	Dry	300	210	115	0.67
	Sandy	170	120	90	0.38
	Wet	300	180	85	0.67
SMOOTH PAINTED CONCRETE	Dry	200	115	55	0.44
	Sandy	120	90	75	0.27
	Wet	180	120	80	0.40

TABLE 4

Skid Resistance Test Results

CONCLUSIONS

Based on the findings of our evaluation program, it is our opinion that the transfer chair has serious shortcomings in the areas of structural integrity, functionality, safety and general operation. These inadequacies make the device unsuitable for a demonstration program involving the general public.

Safety is a concern for two reasons. The exposed leadscrew creates a potential hazard whereby a user's foot or piece of clothing may become entangled in the rotating screw mechanism. Secondly, the inability of the device to absolutely control the descent rate of the chair may create a situation where the user is jostled during his transfer from the coach to ground level.

The resulting structural deformation and weld cracking from the dynamic evaluation program illustrate the requirement to select stronger components and redesign the assembly configuration.

The vibration readings indicate a requirement to improve the drive mechanism and slider assembly to provide smoother operation. The frequent loosening of fasteners due to vibration suggest that substitute fasteners be installed to alleviate the problem, even with a reduction in the measured levels of vibration.

Most adjustments were found to be tedious and insecure. The crosshead attitude adjustment, using wingnuts to control the length of the supporting threaded rods, does not prevent the chair from inadvertently tilting backwards. This situation could be hazardous in the event that a user were to brush against the door or grab bars in the coach entrance on descent.

The device was difficult to manoeuvre over concrete and asphalt surfaces, and bus stairwell positioning was found to be tedious and awkward. The width of GMC and Prevost stairwells inhibit the transfer chair from turning at the landing platform and consequently make it

difficult to transfer a user from the transfer chair to a coach seat.

The floor locks worked well and were simple to operate.

RECOMMENDATIONS

The results of the evaluation program indicate that the following areas require improvement before the transfer chair can be justly evaluated by the operator and user in the marketplace:

1) The welded assemblies should be redesigned to withstand the endurance and operational requirements.

2) The structural assemblies should be redesigned to support the design load without sustaining deformation.

3) The drive mechanism should be covered to prevent the possibility of user and/or clothing entanglement in the leadscrew.

4) The leadscrew, if retained in concept, should be upgraded in material characteristics and size to eliminate bending and subsequent vibration problems.

5) The drive mechanism control system should be redesigned to ensure that the operator will have full control of the device at all times.

6) Alternate casters should be selected to improve the manoeuvrability of the device over typical hallway and sidewalk surfaces.

7) The dolly assembly should be narrowed to facilitate navigation through typical doorway openings.

8) The adjustment and securement method of the seat assembly should be modified to simplify the adjustment procedure and improve safety.

9) The foot rest should be redesigned to provide proper support for the user.

Testing of the device has shown that the operational principle is feasible, however, the concept of the transfer chair requires improvement. T E S Limited recommends that the device be redesigned to improve the structural integrity, drive train mechanism, safety and general operation. The new design should then be tested for operational and structural integrity. When it can be shown that the device will perform its intended function without severe degradation, T E S Limited recommends that the concept be evaluated by typical users at one or more intercity coach terminals.

APPENDIX "E"

ERGONOMIC EVALUATION

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VI. Appendix - Figures

A. Illustrations
B. Photographs

I. Introduction

This section of the report shows photographs taken during the ergonomic evaluation of the Kingston Transfer Chair. This evaluation took place on the premises of RUTENBERG DESIGN INC. in Dorval, Quebec during the months of January and February, 1986.

The Transfer Chair was supplied by Del Can Ltd. and was primarily intended for use at the Montreal (Voyageur) bus terminal.

The model tested by RUTENBERG DESIGN INC. was slightly different to that which was examined by TES LTD. in Ottawa. The differences in the model used by RDI were:

- Manual hand crank was bigger and had a pivoting handle.
- Speed control had no definite "zero" and "stop" position.
- Extension cord measured 6m (20').
- Seat level adjustment was by means of wing nuts.
- Control panel support post was detachable at the bottom position.

The condition of the transfer chair as received by RDI was generally complete and functioning as the mechanical design had been intended. Although, without constant and severe performance testing, the following occurred: The fuse blew continuously; serious vibration of the feed screw was apparent; and considering the unit was not used more than 20 times, the noise level and oscillation of the feed screw during operation had increased significantly since the Transfer Chair was first used by RDI.

Following consultation with TES LTD. we were advised to replace the fuse as supplied, with a "slow-blow" type to overcome initial surge of power.

II. Human Factors Transfer Criteria For Passengers, Operator and Driver

The intention of this transfer chair is to address the problem of boarding and deboarding bus passengers who cannot negotiate bus steps. In order to evaluate any equipment for use by or with this target group, requirements would have to be established based on these criteria for a successful performance and handling. This target group includes:

A. Quadraplegic

B. Paraplegic

C. Crutch User

D. Cane User

E. Walker User

F. Elderly Passengers

Some of the passengers might have the following psychological characteristics: Slower pace for movements and slower reaction time to events and actions. Reduced hearing and visual capabilities. Intimidated by operator/driver. Colour blind.

The criteria for operator and driver includes physical, intellectual, and experience. In the case of a female operator and driver, their physical limitations in assisting passengers e.g. lifting and transfering, as well as manipulating equipment, should also be considered.

Physical criteria: Must be capable of physically lifting (unassisted) a person weighing between 100 and 250 lbs. from a seated position. Must also be capable of maneouvering the Transfer Chair, setting-up, and returning device to storage point

Intellectual criteria: Must have an experience and awareness of simple motor driven machinery and have an understanding of its control and operating limitations.

Experience criteria: Must have a knowledge and training of efficient, safe and dignified transfer methods for all users (both male and female). Must have an appropriate and friendly attitude in regard to the user, in order to reduce fear and anxiety toward the Transfer Chair.

The following paragraphs describe each passenger's PHYSICAL CHARACTERISTICS, the TRANSFER ASSISTANCE required, and the METHOD to be used to achieve this transfer.

A. Quadraplegic

The quadraplegic is a wheelchair user without or little control of upper and lower limbs.

Assistance Required:

Physical lifting of total weight of passenger from wheelchair seat to next seat. Passenger weight can range from 100 to 250 lbs.

Transfer Method:

Wheelchair has to be parked as close as possible to transfer chair, both seats facing in same direction. Wheelchair armrest has to be removable. Transfer can be done by operator standing behind wheelchair, putting his arms under arm pits of passenger, crossing them in front of passenger's chest, bending his knees and lifting by straightening his knees. Lifting and pulling towards transfer chair has to be done simultaneously. This method cannot be used when passenger is a female. It also requires a very strong operator willing to risk injury for himself and passenger.

B. Paraplegic

The paraplegic is a wheelchair user without or little control of lower limbs.

Assistance Required:

1. Physical lifting of total weight of passenger from wheelchair seat to next seat.
2. Providing strong and stable support for passenger's hands in order to stem his own weight out of wheelchair and pull over to next seat.
3. Securing legs and feet and preventing them from sliding sideways or backwards.

Transfer Method:

1. Operator can use method of standing behind passenger with arms around passenger's chest and crossed in front. This position allows the passenger to assist by pulling on operator's forearm to lift himself. Similarly, the operator could stand in front of passenger, bending down so as to allow the passenger to put his arms around operator's neck. The operator straightens his spine to pull passenger out and over to next chair. This method requires a very strong operator and quite strong upper limbs of the passenger.
2. By providing stable hand support at head height with firm grip, passenger can lift himself out of the chair and switch to next chair. Support must be strong enough for a 250 lbs. person.
3. Operator must place the passenger's feet on foot rest and secure position. Not pleasant for female passengers.

C. Crutch User

The crutch user supports most of his body weight on one or two crutches. Crutches serve to support weight and to provide balance. If two crutches are used, they are spread away from passenger, and therefore require more space.

Assistance Required:

Usually no physical assistance from operator is required, as long as passenger can approach seat from the front or side, and use a stable hand support at waist height close to seat.

Transfer Method:

Passenger approaches seat from front or side with crutches, then turns around, backing into the seat. In case of two crutches, one will be switched to the other hand to free the strongest hand or arm. This hand will then grip the support, putting the body weight over it and easing the body backwards or sideways into seat. This method requires unobstructed space in front/side of seat for feet and crutches to move freely, a standard seat height or higher, and an upholstered backrest. Support has to be firm and stable at waist height close to seat. Seat has to be firmly in position, not pivoting. Passenger's feet and legs can usually be positioned by himself on foot rest. Side protection for legs and heel protection for feet are advisable.

D. Cane User

The cane user requires a cane for balancing more than weight support. Many cane users bend their upper body frontwards and use small steps when walking. Their vertical equilibrium axis cannot be changed by large increments.

Assistance Required:

No specific assistance required, except for light support under the forearm, which is not using the cane. Stable hand support to ease in and out of chair and foot/leg clearance in front of seat.

Transfer Method:

The cane user needs to get as close as possible to seat, clearing for feet, legs, and cane. Facing the seat, he then turns 180°, supports one hand

on stable armrest of chair, then releases cane and supports other hand and eases back into chair. Seat height should be reached without bending knees too much. Seat inclination should be minimal in order to get out of chair easier. Feet can be positioned by passenger on foot rest, and protection is advisable.

E. Walker User

The walker user supports some of his weight through both arms onto upper walker handlebar. He then shifts weight by pulling walker up and in front, momentarily taking body weight off walker.

Assistance Required:

No special assistance required, as long as space is available to back up closely against seat and two stable hand supports are provided at waist height.

Transfer Method:

Walker will approach facing seat, then will turn around 180° and back up until touching seat edges. One by one releasing each hand, he will then support body over hand support and ease backwards into seat. Clearance in front of seat required for feet, leg, walker to turn around and stand against seat. Hand support at waist height, close enough to reach easily form standing position.

F. Elderly

The typical elderly passenger can have reduced stamina in arms, legs, balance, and is slightly bent over to the front.

Assistance Required:

Almost no assistance is required, if seat height, seat inclination and hand/arm support are at right height and stable. Clearance space in front of seat necessary for feet and legs.

Transfer Method:

Elderly passenger approaches seat from front, then turns around 180°, supports weight on both hand supports and eases backwards into chair. Seat height should be slightly higher than normal, small seat inclination and firm upholstery,not "sinking" into seat. Clearance for feet and legs infront of seat mandatory.

To Get Out of Seat:

For all passengers who require physical assistance, there must be enough clearance around the transfer chair for standing and bending for the assisting person. For passengers without assistance, a clearance on the floor under the seat edge is required to push both feet back and use this leverage to pull out of seat. Hand supports to pull out should be at armrest height extending over seat edge.

III. Statement of Problems

A. OPERATOR

A1 Picking up device from storage area

1.1 No immediate visible indication or handle bar on device which shows clearly how to manouver device from storage area to place of use. By means of: Canes, boom-end, control panel post?

1.2 Canes are not fixed, they rotate when force is applied and lift out. Steering or directing of device is very difficult. Fixed handle bars are missing. Device requires 36" doorway clearance, minimum. Fig.1

1.3 Boomhead height is at eye level of standing/walking person, no warning markings, dangerous to other terminus users.

1.4 Casters have too little clearance for actual conditions of environment. Floor surfaces being carpet, terrazzo, concrete & asphalt. Surfaces can be uneven, slippery, snow covered... A threshold ½" high hooks casters. Curbs (6-7" high) cannot but might have to be negotiated.

A2 Setting up device in bus stairwell

2.1 Clearance of 8 ft. required in front of bus door opening to allow for manouvering of device. Is bus door hooked safely in open position?

2.2 No visual references for proper and safe positioning of transfer chair. Requirements being: Distance guide from edge of first step to dolly; centering of boom inside the stairwell for clearance; distance of boom support leg from edge of top step; height adjustment of boom support leg. No levelling of boom support leg to stabilize device.

2.3 No visual information on adjusting seat inclination of transfer chair. Leveling chair is complicated (requires 4 wing nuts). Chair tilts backwards (unstable), not fixed to support frame (crosshead). Chair rotates freely, no locking mechanism to position it. Fig. 2

2.4 "Cordomatic" difficult to operate, opening is at bottom but cord is pulled in horizontal direction. Other passengers can trip over cord and disengage plug. Fig. 3

A3 Transfer of user into Transfer Chair

3.1 Canes obstruct operator when transferring passenger. No place to put canes if removed. No step for user to stand on. Footrest is only visible support, too high from ground level and doesn't support weight of user. Fig. 4

3.2 QUADRIPLEGIC. Paralysis of all four limbs. Wheelchair transfer: Operator required to lift passenger (200-250 lbs.) from wheelchair to transfer chair, unassisted. Height difference between wheelchair seat and transfer chair seat, 3-4". No space clear around transfer chair for operator to lift passenger effectively. Fig. 5

3.3 PARAPLEGIC. Paralysis of lower limbs. No hand support on transfer chair. Operator must physically support upper body of passenger. Fig. 6

3.4 CRUTCH USER requires room to stand as close as possible to the seat, and to ease in. Impossible due to protruding foot rest and frame ends. No support for arms on chair, chair moves. Fig. 7, 8 & 9

3.5 CANE USER (similar difficulties as crutch user). Support for hand is needed to stabilize upper body, clearance for feet and legs required. footrest and frame ends are obstacles.

3.6 ELDERLY. No hand supports on each side of chair. Elderly tend to drop into the backrest. Footrest is barrier. Chair moves and pivots.

3.7 Chair not wide enough to accomodate obese passengers.

3.8 Transfer chair on lowest boom position should adjust to different user heights and maintain appropriate accessibility.

A4 Operation from control panel

4.1 Operator needs to view passenger at all times. Position control panel facing the bus door opening.

4.2 No obvious visual procedural steps related to operation of device. No instructions near control panel for setting up and for operating transfer chair. Fig. 10

4.3 Important switches require fine finger manipulation (very difficult while wearing gloves). No sequence provided of operating. ON-OFF, REVERSE

and FORWARD switches are too close for positive feedback. Variable speed control: increments are not related to speed or disability of passenger and control does not have physical zero stop position. FORWARD - REVERSE; which means UP? DOWN? Fig. 11 & 12

4.4 An automatic reset to OFF is not provided when cord is accidentally pulled from outlet in mid operation (dangerous for user) and plugged in again, without resetting controls before.

4.5 CONTROL panel isn't tamper proof, canvas bag is the only protection. Fuse too easily removed when unattended. Key switch should be provided.

A5 Preparing for storage

5.1 Sequence for returning device to "rest position" isn't evident.

5.2 FLOOR LOCKS (foot operated) are difficult to release from lock position. Fig. 13

5.3 Manouvering back into storage creates same problems as in 1.1-1.4.

B1 Approaching the transfer chair

1.1 The chair is not an obvious dominating feature of the device. Barriers on all sides, two canes (removable) and foot rest to front, control panel at side. No obvious place of entrance. Fig. 14

B2 Getting into the chair

2.1 Canes are the only visible means of support, but they move when physical force is applied. Seat also rotates when backrest is used as support. Fig.15

2.2 Seat is 22½" from ground at lowest position and requires step to aid user into chair. Foot rest is the only VISIBLE step, which doesn't support the weight of the USER when stepped on.

2.3 Foot rest extends 12" in front of chair, (even when flaps are folded up). Foot rest hinders ease of entry.

2.4 Exposed metal edges of the seat structure make sitting uncomfortable. Width of seat is for small adult. Backrest too low, too far forward, provides inadequate support. Fig. 16

B3 Travel of transfer chair along the boom

3.1 No seat position locking mechanism against pivoting (dangerous for passenger). Fig. 17

3.2 Passengers travelling backwards cannot see where they are going, must rely on operator.

3.3 Minimal protection for the user. No protection from side to elbows (arms in sitting position). Foot rest doesn't guard front and side of feet and legs (important for passengers without control of lower limbs). Heel area is exposed. Toe end of shoe projects, inadequate relationship between seat height and foot rest position. Fig. 18, 19 & 20

3.4 Seat belt is questionable for disabled user due to physical contact required when assisted during transfer from wheelchair, alternate restraint required. Fig. 21

3.5 No indication on foot rest support for lowest position. Foot rest hits motor unit if comfortable seat height - foot rest position is achieved. Fig. 22

3.6 No protection for motor against accidental damage or weather. (e.g. slush, rain)

3.7 FEED SCREW is exposed the full length of the boom. Clothing and unprotected limbs of user are vulnerable to the spinning feed screw. Top surface of boom GLIDE TRACK is grease coated and therefore poses problems to operator/user/driver if handled or touched with clothing. Fig. 23, 24 & 25

B4 Getting out of the chair

4.1 Driver must turn chair, 36" clearance required for turning. No definite handle to turn chair around, physical contact required to turn user to face aisle. Fig. 26

4.2 Inside bus, no hand supports to aid passenger in leaving seat. At ground level, canes are not fixed. No steps near seat to help user down from chair.

4.3 Chair can only be turned approximately 100° then hits boom.

4.4 Definite clearance zone required for passenger when stepping out of chair: 24" + safety from past step edge to inside of bus. No indication as to how far boom should move into bus to clear for transfer. Fig. 27

C1 Setting up device in bus stairwell

1.1 End of boomhead support leg doesn't suggest its function (looks like it has to fit into channel). Removal of two pins required to adjust height (to what level?). Pins are not positively attached, can get lost. Boom leg can drop out of frame when not secured.

1.2 Manual operation takes 4 minutes for transfer chair to travel from bus floor to ground level. Driver bends over to turn crank at boom end (16" above floor). Position for CRANK isn't obvious. Storage place not provided. Operates from top of boom only. Who does the cranking? Fig. 28

C2 Transfer of user into bus seat

2.1 Substantial physical effort required for paraplegics and quadriplegics by operator/driver. Limited physical effort for crutch users, cane users and the elderly.

2.2 Is bus seat always directly adjacent to transfer seat? What if there is another step? (Prevost bus)

2.3 What happens if more than one disabled person is boarding? Are there always two seats adjacent to the transfer chair?

2.4 Limited space around transfer chair for operator to assist passenger.

IV. Conclusion

Based on the evaluation, measured against the criteria required for passenger, operator and driver, it is felt that the Kingston Transfer Chair has not been developed with sufficient consideration. Therefore, it makes it unsuitable for use by the disabled passenger, for whom it was intended, or for the operator/driver who has to maneouver and operate this device on a regular basis. It is obvious throughout this evaluation that a great number of basic requirements of the user, operator, and driver were not considered and applied to the design of the Transfer Chair.

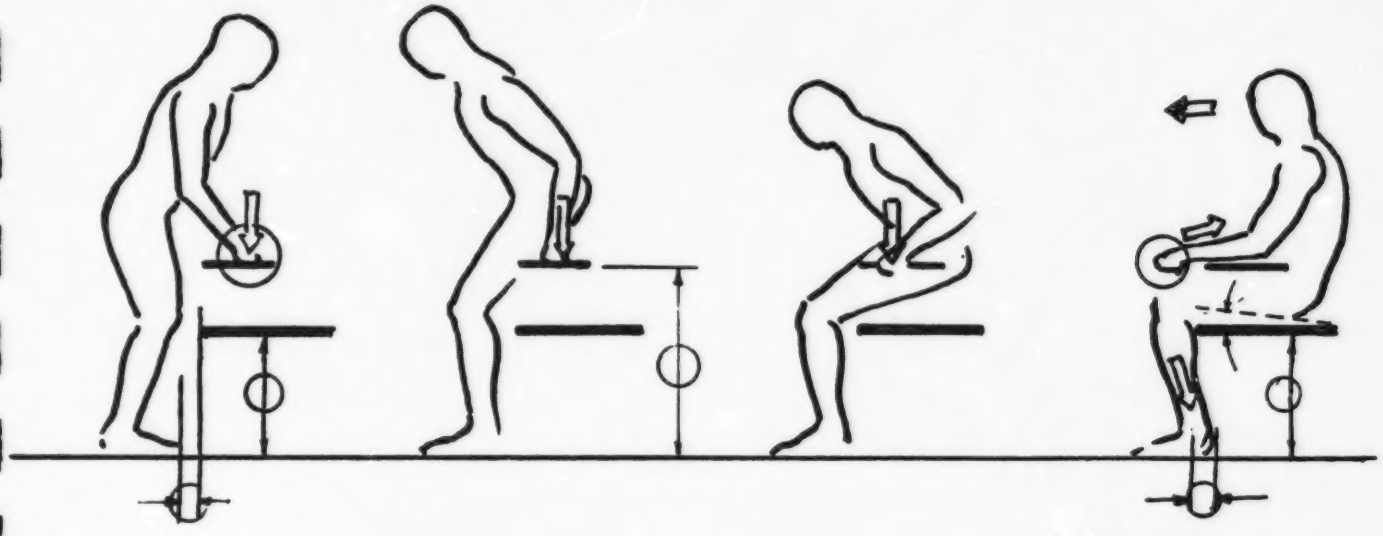
V. Recommendation

It is therefore recommended that before any further design and development work is done on this Transfer Chair, a feasability study be undertaken. This study should consider fully the requirements of the user,operator, and driver. Performance requirements of the Transfer Chair and a systems approach applying the design to the bus industry sector should be researched more thoroughly. These crucial factors are missing form the initial concept.

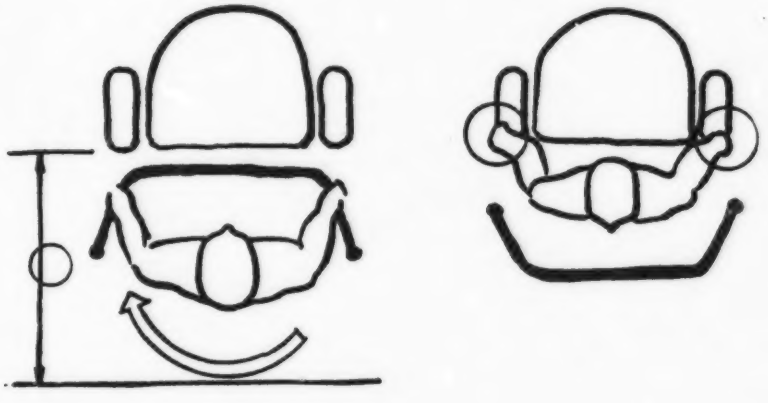
VI. Appendix - Figures

A. Illustrations

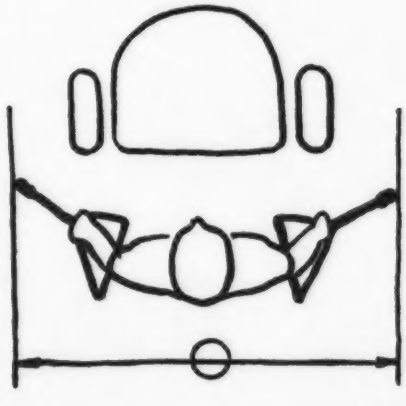
HUMAN FACTORS TRANSFER CRITERIA



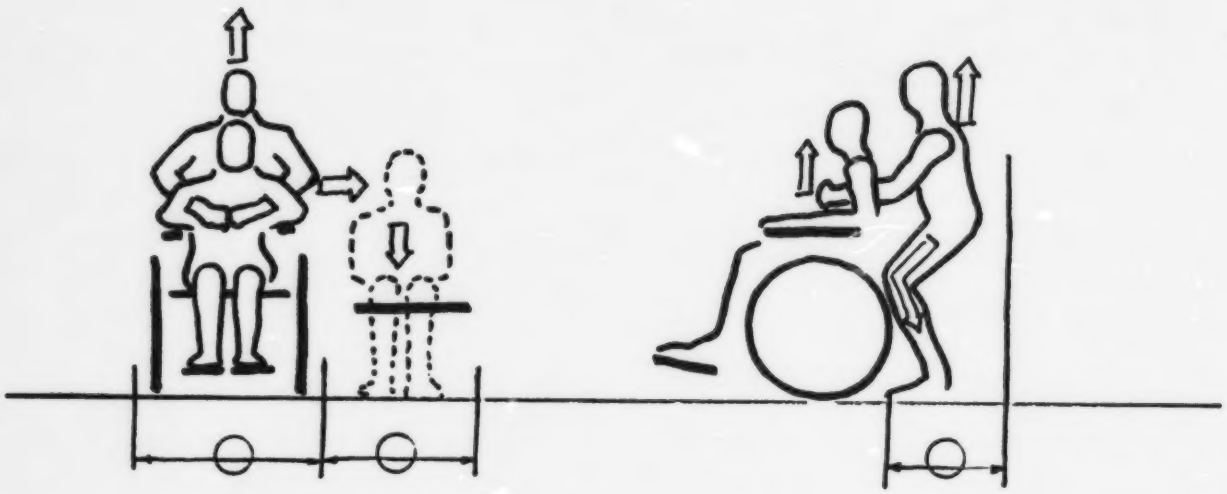
ELDERLY.



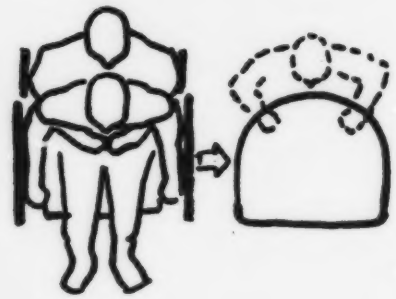
WALKER - USER.

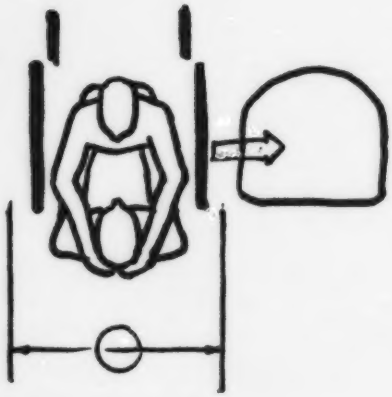


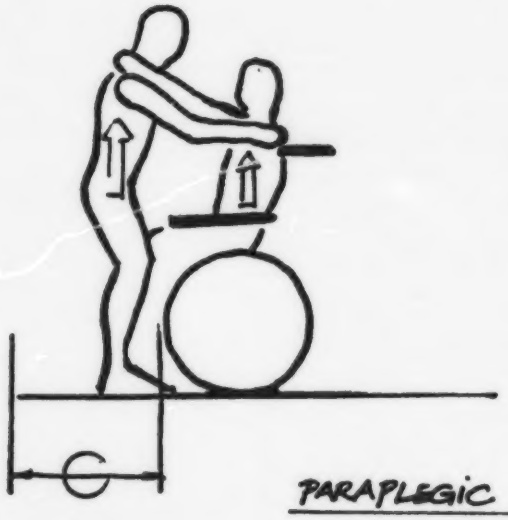
CRUTCH, CANE USER



QUADRAPLEGIC





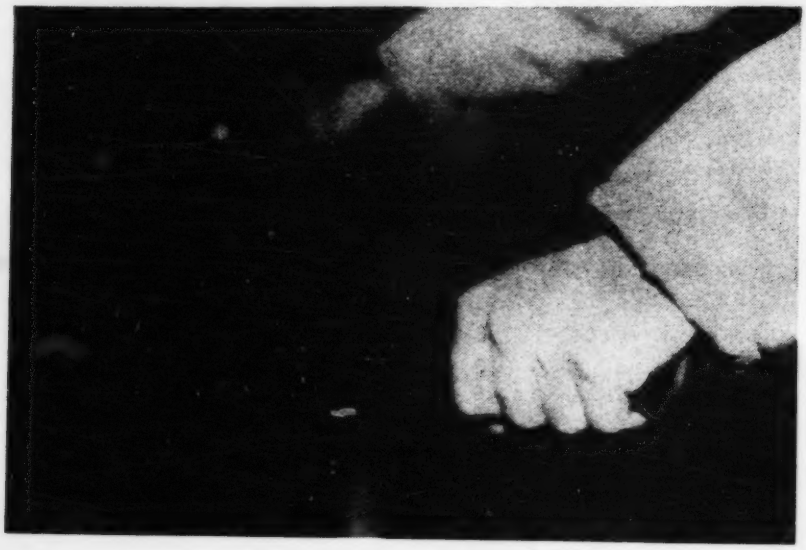


PARAPLEGIC

VI. Appendix - Figures

B. Photographs

Fig. 1 - Canes are not fixed, they rotate when force is applied and lift out.



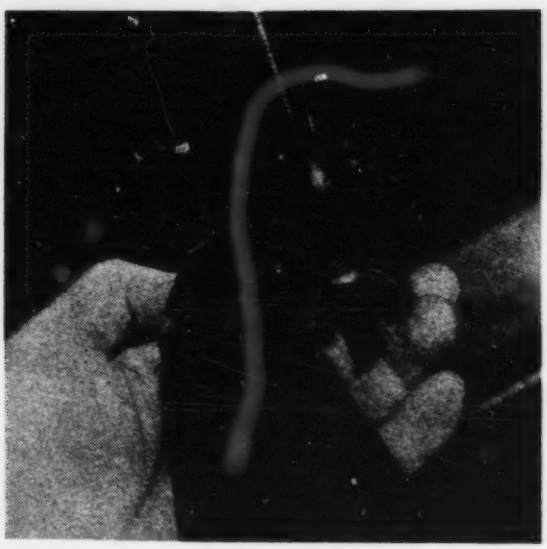


Fig. 2 - No information on adjusting seat angle. Leveling of chair is complicated.

Fig. 3 - "Cordomatic" difficult to operate. Opening at bottom but pull should be horizontal.

Fig. 4 - Canes obstruct when passenger transfers.

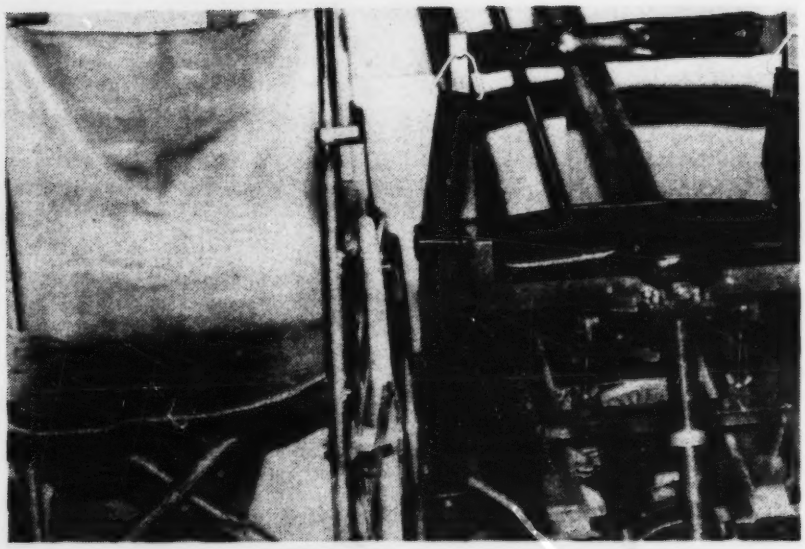
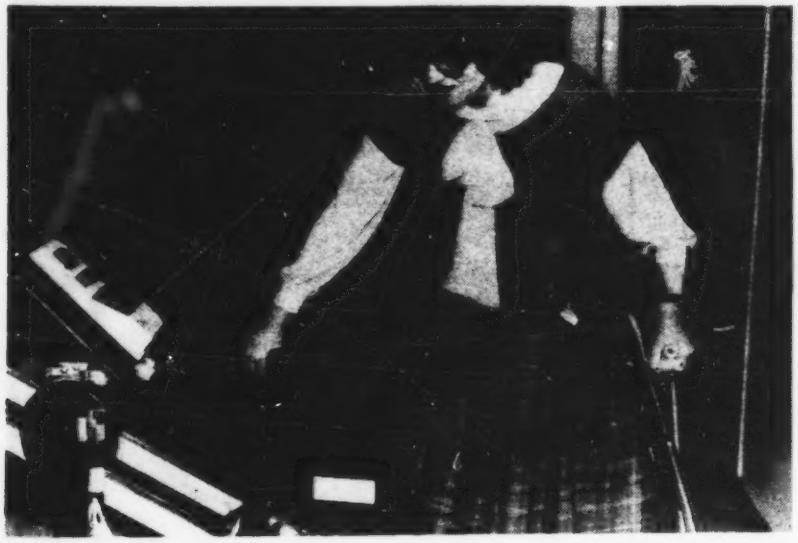


Fig. 5 - Transfer Chair seat height not suitable for transfer from a wheelchair. Height difference 3-4".

Fig. 6 - Operator required to lift lower limb paraplegic or quadraplegic passenger (200-250 lbs.) from wheelchair to Transfer Chair, unassisted.

Fig. 7 & 8 - Crutch user requires room to stand close to seat. Projections and no stable support create hazards.

Fig. 9 - Chair cannot be fixed and moves when used for support when sitting. Not adjustable to different user heights.



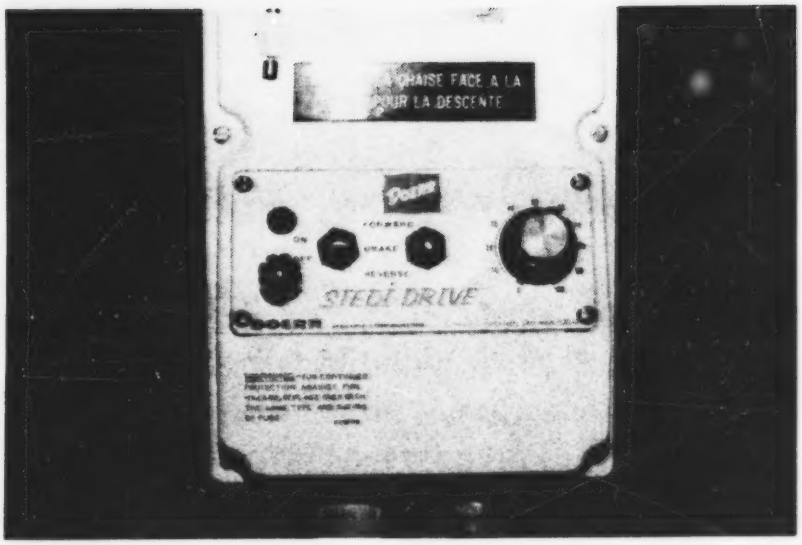


Fig. 10 - No obvious procedural steps related to operation of device. No instructions near control panel on set-up.

Fig. 11 - Important switches require fine finger manipulation, very difficult while wearing gloves.

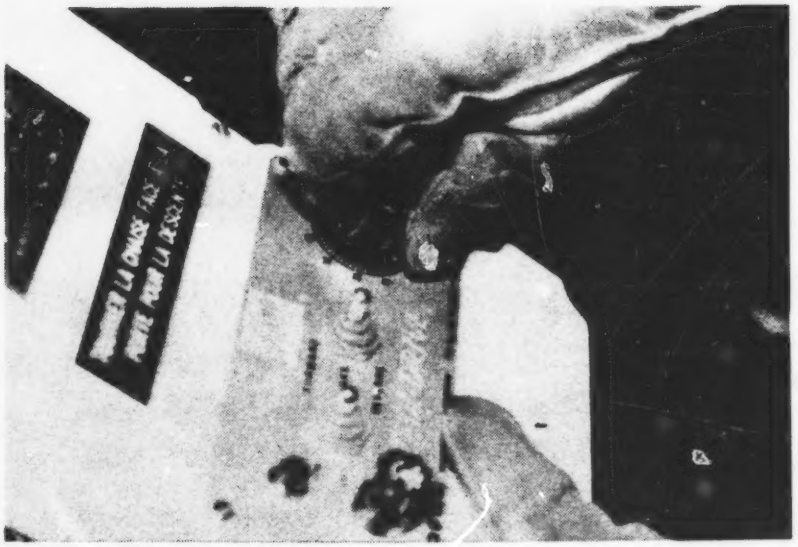
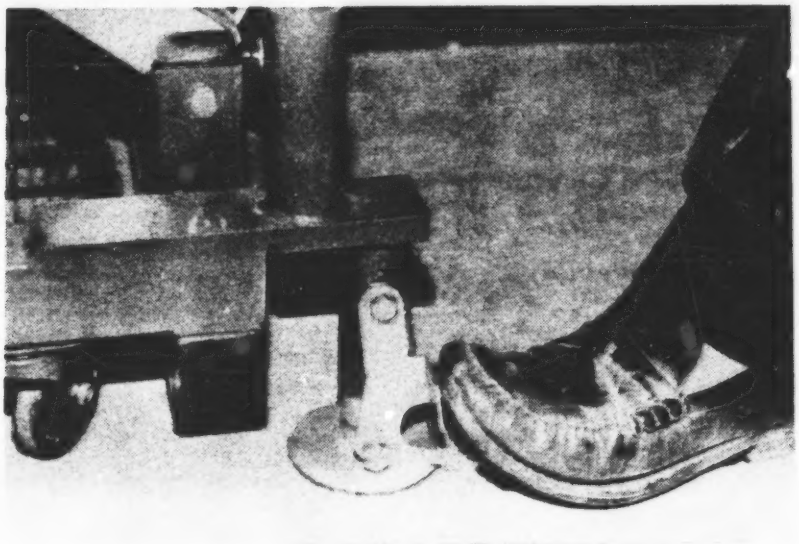


Fig. 12 - On/Off, REVERSE and FORWARD switches are too close for positive feedback. Variable speed control increments not related to either speed or disability of passenger. Physical zero stop position not provided.

Fig. 13 - Floor locks (foot operated) are difficult to release from lock position.



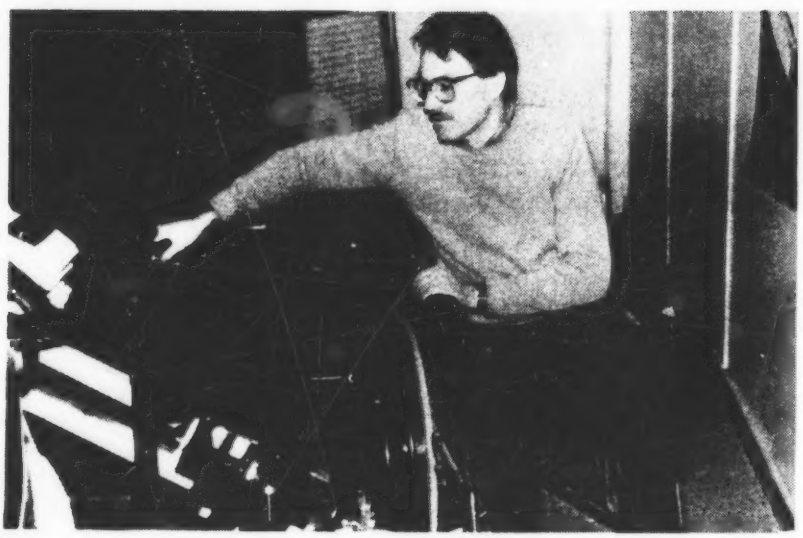


Fig. 14 - No ovbious dominating feature. Barriers on all sides. No obvious point of entrance.

Fig. 15 - Canes are only visible means of support, but move when force applied.

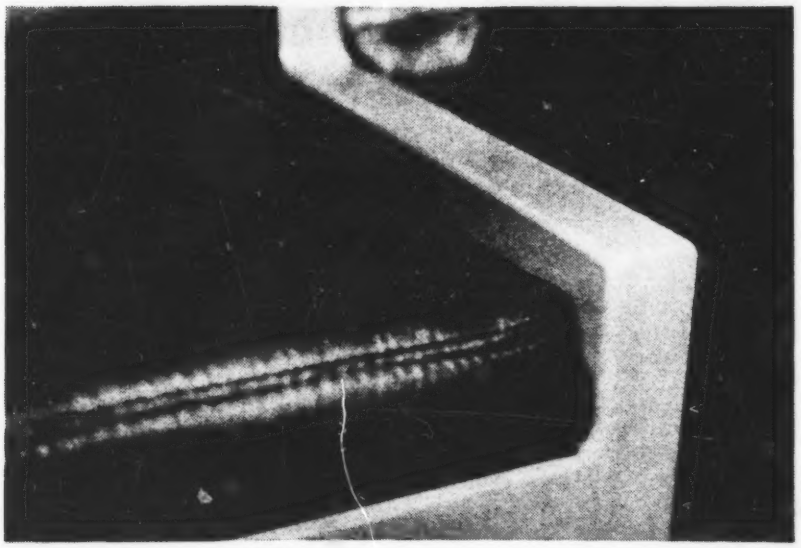
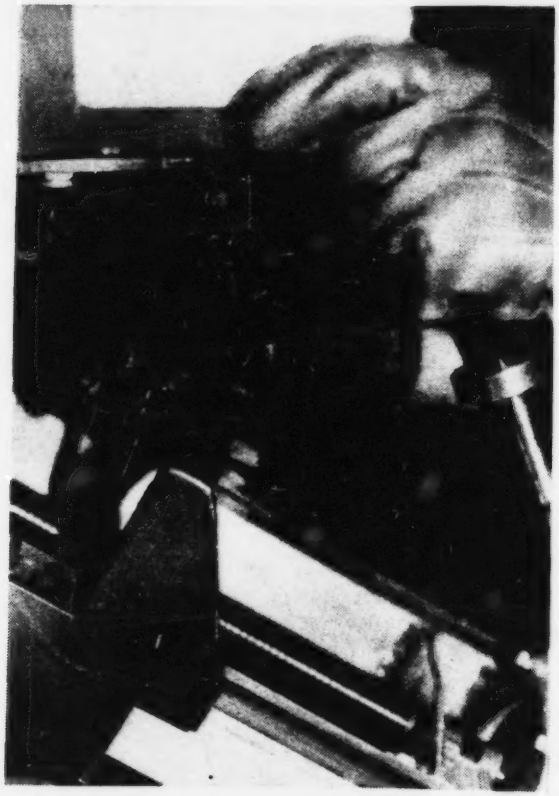


Fig. 16 - Exposed metal edges of seat structure make sitting uncomfortable and prevent unobstructed transfer.

Fig. 17 - No seat position locking mechanism against pivoting.



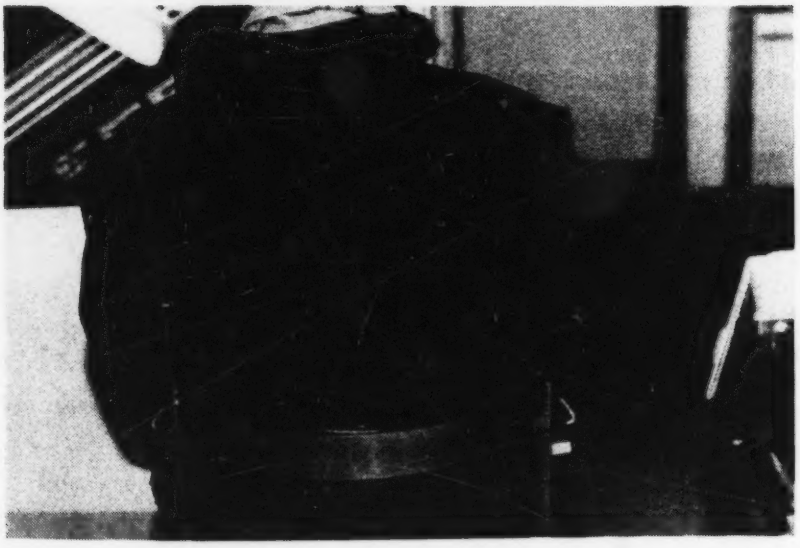


Fig. 18 - Minimal protection for the user. No protection to the side for arms and elbows in sitting position.

Fig. 19 - Foot rest doesn't guard front, side, and back of feet and legs.

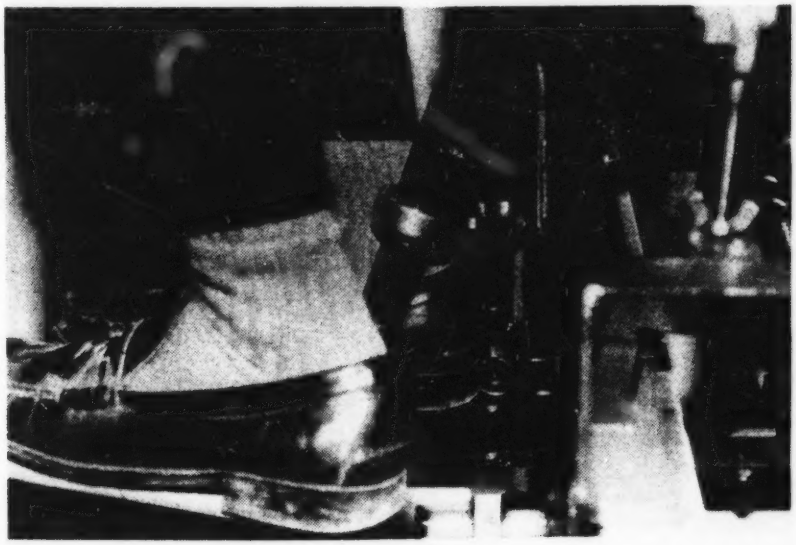


Fig. 20 - Toe end of shoe projects. Inadequate relationship between seat height and foot rest position.

Fig. 21 - Seat belt type restraint is questionable for the disabled user.

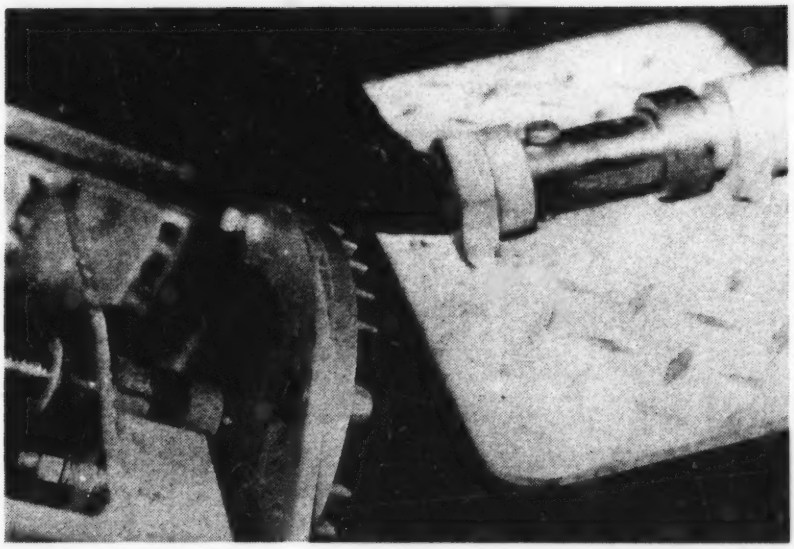


Fig. 22 - Foot rest hits motor unit when comfortable seat height - foot rest position achieved.

Fig. 23 - Feed screw is exposed full length of boom. Clothing and unprotected limbs of user are vulnerable to spinning screw.

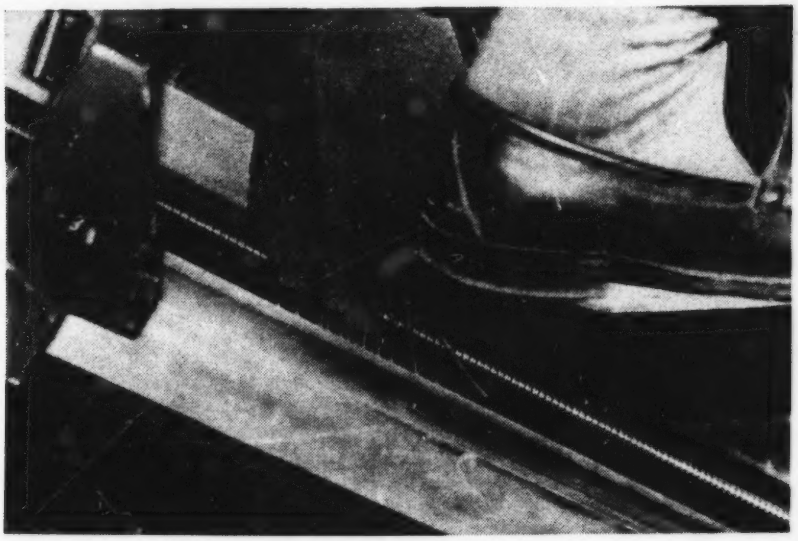
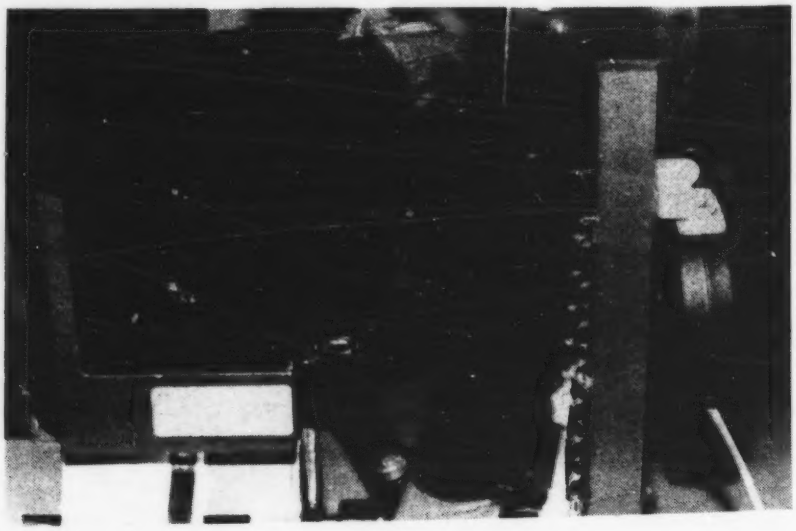


Fig. 24 - Top suface of boom glide track is grease coated and therefore, makes handling problems for operator/user/driver.

Fig. 25 - If passenger taken up boom sideways knees will catch on control panel and support. No warning or mechanical device provided to prohibit such use.



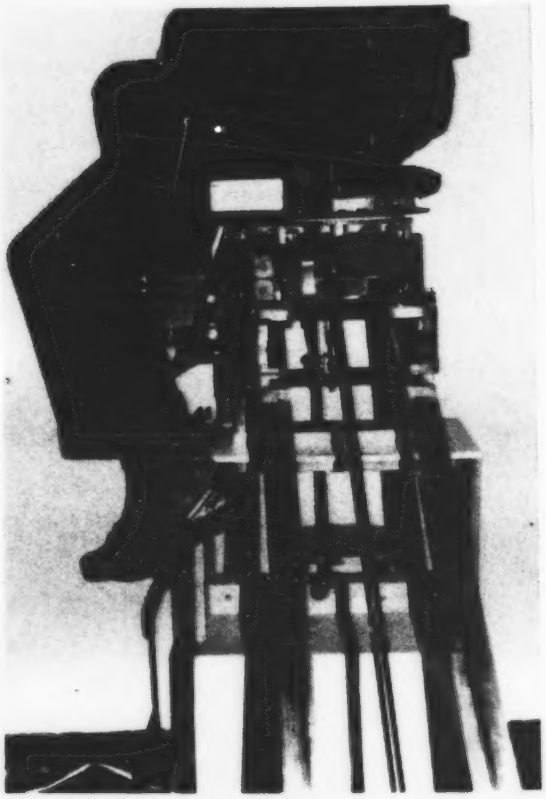


Fig. 26 - Driver must turn chair to face aisle. 36" clearance required for this. No handle provided for doing this.

Fig. 27 - No steps near seat to help user down from chair. Definite clearance zone required for passenger when stepping out of chair.

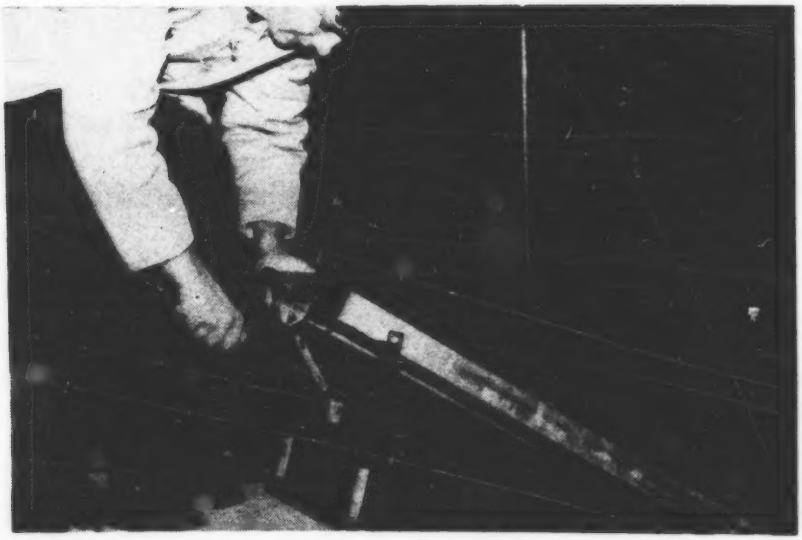


Fig. 28 - End of boom head support leg doesn't suggest its function. Manual operation takes 4 minutes for transfer chair to travel from bus floor to ground level. Crank operates from top of boom only.

Fig. 29 - Rear transfer of paraplegic with limited or no hand and arm strength requires more exertion from operator.

Fig. 30 - From position behind passenger in wheelchair, the physical aspects of the wheelchair create awkward and uncomfortable positions for the operator.

Fig. 29

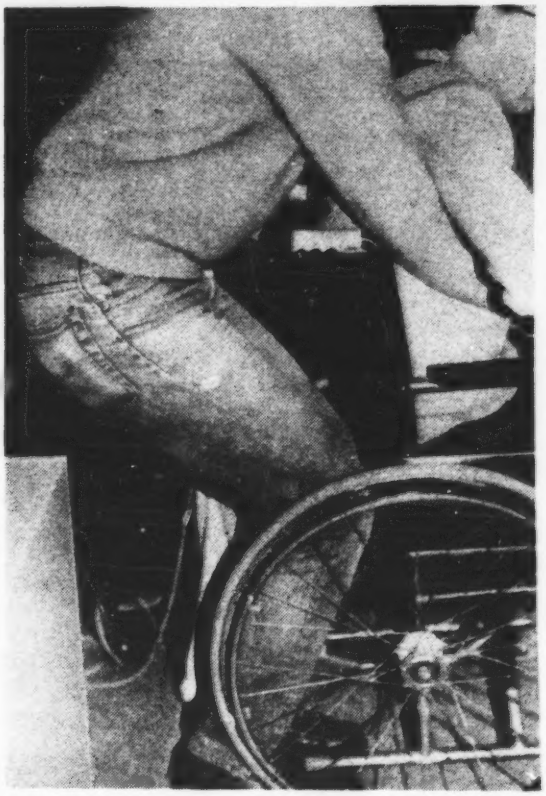


Fig. 30

Fig. 31 - In this position during transfer the control panel obstructs the operator making lifting procedure difficult and potentially strenuous.

Fig. 32 & 33 - Front transfer of lower limb paraplegic with strength in arms and hands, provides a more effecient means of transfer to chair. Operator and driver require training in alternative techniques used for transfer.

Fig. 32

Fig. 33